Red Hat Enterprise Linux 6 Storage Administration Guide

Deploying and configuring single-node storage in Red Hat Enterprise Linux 6

Edition 2

Red Hat Subject Matter ExpertsJosef Bacik

Kamil Dudka	Hans de Goede	Doug Ledford
Daniel Novotny	Nathan Straz	David Wysochanski
Contributors	Michael Christie	Sachin Prabhu
Rob Evers	David Howells	David Lehman
Jeff Moyer	Eric Sandeen	Mike Snitzer

Red Hat Enterprise Linux 6 Storage Administration Guide

Deploying and configuring single-node storage in Red Hat Enterprise Linux 6
Edition 2

Josef Bacik
Server Development Kernel File System
jwhiter@redhat.com
Disk Quotas

Kamil Dudka
Base Operating System Core Services - BRNO
kdudka@redhat.com
Access Control Lists

Hans de Goede
Base Operating System Installer
hdegoede@redhat.com
Partitions

Doug Ledford
Server Development Hardware Enablement
dledford@redhat.com
RAID

Daniel Novotny
Base Operating System Core Services - BRNO
dnovotny@redhat.com
The /proc File System

Nathan Straz
Quality Engineering QE - Platform
nstraz@redhat.com
GFS2

David Wysochanski
Server Development Kernel Storage
dwysocha@redhat.com
LVM/LVM2

Michael Christie
Server Development Kernel Storage
mchristi@redhat.com
Online Storage

Sachin Prabhu
Software Maintenance Engineering
sprabhu@redhat.com
NFS

Rob Evers
Server Development Kernel Storage

revers@redhat.com
Online Storage

David Howells
Server Development Hardware Enablement
dhowells@redhat.com
FS-Cache

David Lehman
Base Operating System Installer
dlehman@redhat.com
Storage configuration during installation

Jeff Moyer
Server Development Kernel File System
jmoyer@redhat.com
Solid-State Disks

Eric Sandeen
Server Development Kernel File System
esandeen@redhat.com
ext3, ext4, XFS, Encrypted File Systems

Mike Snitzer
Server Development Kernel Storage
msnitzer@redhat.com
I/O Stack and Limits

Red Hat Subject Matter Experts

Contributors

Edited by

Jacquelynn East
Engineering Content Services
jeast@redhat.com

Don Domingo
Engineering Content Services
ddomingo@redhat.com

Legal Notice

Copyright © 2013 Red Hat Inc. and others.

This document is licensed by Red Hat under the Creative Commons Attribution-ShareAlike 3.0 Unported License. If you distribute this document, or a modified version of it, you must provide attribution to Red Hat, Inc. and provide a link to the original. If the document is modified, all Red Hat trademarks must be removed.

Red Hat, as the licensor of this document, waives the right to enforce, and agrees not to assert, Section 4d of CC-BY-SA to the fullest extent permitted by applicable law.

Red Hat, Red Hat Enterprise Linux, the Shadowman logo, JBoss, MetaMatrix, Fedora, the Infinity Logo, and RHCE are trademarks of Red Hat, Inc., registered in the United States and other countries.

Linux ® is the registered trademark of Linus Torvalds in the United States and other countries.

Java ® is a registered trademark of Oracle and/or its affiliates.

XFS ® is a trademark of Silicon Graphics International Corp. or its subsidiaries in the United States and/or other countries.

MySQL ® is a registered trademark of MySQL AB in the United States, the European Union and other countries.

Node.js ® is an official trademark of Joyent. Red Hat Software Collections is not formally related to or endorsed by the official Joyent Node.js open source or commercial project.

The OpenStack ® Word Mark and OpenStack Logo are either registered trademarks/service marks or trademarks/service marks of the OpenStack Foundation, in the United States and other countries and are used with the OpenStack Foundation's permission. We are not affiliated with, endorsed or sponsored by the OpenStack Foundation, or the OpenStack community.

All other trademarks are the property of their respective owners.

Abstract

This guide provides instructions on how to effectively manage storage devices and file systems on Red Hat Enterprise Linux 6. It is intended for use by system administrators with basic to intermediate knowledge of Red Hat Enterprise Linux or Fedora.

Table of Contents

Preface **8**
1. Document Conventions 8
1.1. Typographic Conventions 8
1.2. Pull-quote Conventions 9
1.3. Notes and Warnings 10
2. Getting Help and Giving Feedback 10
2.1. Do You Need Help? 10
2.2. We Need Feedback 11

Chapter 1. Overview **12**
1.1. What's New in Red Hat Enterprise Linux 6 12

File System Encryption (Technology Preview) **12**

File System Caching (Technology Preview) **12**

Btrfs (Technology Preview) **12**

I/O Limit Processing **12**

ext4 Support **12**

Network Block Storage **13**

Part I. File Systems **14**

Chapter 2. File System Structure and Maintenance **15**
2.1. Overview of Filesystem Hierarchy Standard (FHS) 15
2.1.1. FHS Organization 15
2.1.1.1. Gathering File System Information 15
2.1.1.2. The /boot/ Directory 17
2.1.1.3. The /dev/ Directory 17
2.1.1.4. The /etc/ Directory 18
2.1.1.5. The /lib/ Directory 18
2.1.1.6. The /media/ Directory 18
2.1.1.7. The /mnt/ Directory 18
2.1.1.8. The /opt/ Directory 18
2.1.1.9. The /proc/ Directory 19
2.1.1.10. The /sbin/ Directory 19
2.1.1.11. The /srv/ Directory 19
2.1.1.12. The /sys/ Directory 20
2.1.1.13. The /usr/ Directory 20
2.1.1.14. The /var/ Directory 21
2.2. Special Red Hat Enterprise Linux File Locations 23
2.3. The /proc Virtual File System 23
2.4. Discard unused blocks 24

Chapter 3. Encrypted File System **25**
3.1. Mounting a File System as Encrypted 25
3.2. Additional Information 26

Chapter 4. Btrfs **27**
4.1. Btrfs Features 27

Chapter 5. The Ext3 File System **28**

5.1. Creating an Ext3 File System 29
5.2. Converting to an Ext3 File System 29
5.3. Reverting to an Ext2 File System 30

Chapter 6. The Ext4 File System 32
6.1. Creating an Ext4 File System 33
6.2. Mounting an Ext4 File System 34

Write Barriers 34
6.3. Resizing an Ext4 File System 35
6.4. Backup ext2/3/4 File Systems 35
6.5. Restore an ext2/3/4 File System 37
6.6. Other Ext4 File System Utilities 38

Chapter 7. Global File System 2 40

Chapter 8. The XFS File System 41
8.1. Creating an XFS File System 41
8.2. Mounting an XFS File System 42

Write Barriers 43
8.3. XFS Quota Management 43

Setting Project Limits 45
8.4. Increasing the Size of an XFS File System 45
8.5. Repairing an XFS File System 45
8.6. Suspending an XFS File System 46
8.7. Backup and Restoration of XFS File Systems 46

Simple Mode for xfsrestore 48

Cumulative Mode for xfsrestore 48

Interactive Operation 48
8.8. Other XFS File System Utilities 49

Chapter 9. Network File System (NFS) 50
9.1. How NFS Works 50
9.1.1. Required Services 51
9.2. pNFS 52
9.3. NFS Client Configuration 53
9.3.1. Mounting NFS File Systems using /etc/fstab 54
9.4. autofs 54
9.4.1. Improvements in autofs Version 5 over Version 4 55
9.4.2. autofs Configuration 56
9.4.3. Overriding or Augmenting Site Configuration Files 58
9.4.4. Using LDAP to Store Automounter Maps 59
9.5. Common NFS Mount Options 60
9.6. Starting and Stopping NFS 62
9.7. NFS Server Configuration 63
9.7.1. The /etc/exports Configuration File 63
9.7.2. The exportfs Command 65
9.7.2.1. Using exportfs with NFSv4 66
9.7.3. Running NFS Behind a Firewall 66
9.7.3.1. Discovering NFS exports 67
9.7.4. Hostname Formats 68
9.7.5. NFS over RDMA 68

9.7.3. NFS over RDMA 68
9.8. Securing NFS 69
9.8.1. NFS Security with AUTH_SYS and export controls 69
9.8.2. NFS security with AUTH_GSS 70
9.8.2.1. NFS security with NFSv4 70
9.8.3. File Permissions 71
9.9. NFS and rpcbind 71
9.9.1. Troubleshooting NFS and rpcbind 71
9.10. References 72

Installed Documentation ... **72**

Useful Websites ... **73**

Related Books ... **73**

Chapter 10. FS-Cache ... **74**
10.1. Performance Guarantee 75
10.2. Setting Up a Cache 75
10.3. Using the Cache With NFS 76
10.3.1. Cache Sharing 76
10.3.2. Cache Limitations With NFS 77
10.4. Setting Cache Cull Limits 78
10.5. Statistical Information 79
10.6. References 79

Part II. Storage Administration ... **80**

Chapter 11. Storage Considerations During Installation ... **81**
11.1. Updates to Storage Configuration During Installation 81
11.2. Overview of Supported File Systems 81
11.3. Special Considerations 82

Separate Partitions for /home, /opt, /usr/local ... **82**

DASD and zFCP Devices on IBM System Z ... **82**

Encrypting Block Devices Using LUKS ... **83**

Stale BIOS RAID Metadata ... **83**

iSCSI Detection and Configuration ... **83**

FCoE Detection and Configuration ... **83**

DASD ... **83**

Block Devices with DIF/DIX Enabled ... **83**

Chapter 12. File System Check ... **85**
12.1. Best Practices for fsck 85
12.2. Filesystem-Specific Information for fsck 86
12.2.1. ext2, ext3, and ext4 86
12.2.2. XFS 87
12.2.3. Btrfs 89

Chapter 13. Partitions ... **90**
13.1. Viewing the Partition Table 91
13.2. Creating a Partition 92

13.2.1. Making the Partition 92
13.2.2. Formatting and Labeling the Partition 93
13.2.3. Add to /etc/fstab 93
13.3. Removing a Partition 94
13.4. Resizing a Partition 94

Chapter 14. LVM (Logical Volume Manager) 96
14.1. What is LVM2? 97
14.2. Using system-config-lvm 97
14.2.1. Utilizing Uninitialized Entities 100
14.2.2. Adding Unallocated Volumes to a Volume Group 101
14.2.3. Migrating Extents 104
14.2.4. Adding a New Hard Disk Using LVM 106
14.2.5. Adding a New Volume Group 107
14.2.6. Extending a Volume Group 108
14.2.7. Editing a Logical Volume 110
14.3. LVM References 113

Installed Documentation 113

Useful Websites 113

Chapter 15. Swap Space 114
15.1. Adding Swap Space 114
15.1.1. Extending Swap on an LVM2 Logical Volume 115
15.1.2. Creating an LVM2 Logical Volume for Swap 115
15.1.3. Creating a Swap File 116
15.2. Removing Swap Space 116
15.2.1. Reducing Swap on an LVM2 Logical Volume 116
15.2.2. Removing an LVM2 Logical Volume for Swap 117
15.2.3. Removing a Swap File 117
15.3. Moving Swap Space 118

Chapter 16. Disk Quotas 119
16.1. Configuring Disk Quotas 119
16.1.1. Enabling Quotas 119
16.1.2. Remounting the File Systems 120
16.1.3. Creating the Quota Database Files 120
16.1.4. Assigning Quotas per User 121
16.1.5. Assigning Quotas per Group 122
16.1.6. Setting the Grace Period for Soft Limits 123
16.2. Managing Disk Quotas 123
16.2.1. Enabling and Disabling 123
16.2.2. Reporting on Disk Quotas 123
16.2.3. Keeping Quotas Accurate 124
16.3. Disk Quota References 125

Chapter 17. Redundant Array of Independent Disks (RAID) 126
17.1. RAID Types 126

Firmware RAID 126

Hardware RAID 126

Software RAID 127
17.2. RAID Levels and Linear Support 127

17.3. Linux RAID Subsystems 129

Linux Hardware RAID controller drivers 129

mdraid 129

dmraid 130

17.4. RAID Support in the Installer 130

17.5. Configuring RAID Sets 130

mdadm 130

dmraid 130

17.6. Advanced RAID Device Creation 131

Chapter 18. Using the mount Command 133

18.1. Listing Currently Mounted File Systems 133

18.1.1. Specifying the File System Type 133

18.2. Mounting a File System 134

18.2.1. Specifying the File System Type 135

18.2.2. Specifying the Mount Options 136

18.2.3. Sharing Mounts 137

18.2.4. Moving a Mount Point 140

18.3. Unmounting a File System 141

18.4. mount Command References 141

18.4.1. Manual Page Documentation 142

18.4.2. Useful Websites 142

Chapter 19. The volume_key function 143

19.1. Commands 143

19.2. Using volume_key as an individual user 144

19.3. Using volume_key in a larger organization 145

19.3.1. Preparation for saving encryption keys 145

19.3.2. Saving encryption keys 146

19.3.3. Restoring access to a volume 146

19.3.4. Setting up emergency passphrases 147

19.4. volume_key References 147

Chapter 20. Access Control Lists 148

20.1. Mounting File Systems 148

20.1.1. NFS 148

20.2. Setting Access ACLs 148

20.3. Setting Default ACLs 149

20.4. Retrieving ACLs 150

20.5. Archiving File Systems With ACLs 150

20.6. Compatibility with Older Systems 151

20.7. ACL References 151

Chapter 21. Solid-State Disk Deployment Guidelines 153

21.1. Deployment Considerations 153

21.2. Tuning Considerations 154

I/O Scheduler 154

Virtual Memory 154

Swap 154

Chapter 22. Write Barriers **155**
22.1. Importance of Write Barriers 155

How Write Barriers Work **155**
22.2. Enabling/Disabling Write Barriers 155
22.3. Write Barrier Considerations 156

Disabling Write Caches **156**

Battery-Backed Write Caches **156**

High-End Arrays **157**

NFS **157**

Chapter 23. Storage I/O Alignment and Size **158**
23.1. Parameters for Storage Access 158
23.2. Userspace Access 159

sysfs Interface **159**

Block Device ioctls **159**
23.3. Standards 160

ATA **160**

SCSI **160**
23.4. Stacking I/O Parameters 160
23.5. Logical Volume Manager 161
23.6. Partition and File System Tools 161

util-linux-ng's libblkid and fdisk **161**

parted and libparted **162**

File System tools **162**

Chapter 24. Setting Up A Remote Diskless System **163**
24.1. Configuring a tftp Service for Diskless Clients 163
24.2. Configuring DHCP for Diskless Clients 163
24.3. Configuring an Exported File System for Diskless Clients 164

Chapter 25. Online Storage Management **166**
25.1. Fibre Channel 166
25.1.1. Fibre Channel API 166
25.1.2. Native Fibre Channel Drivers and Capabilities 167
25.2. iSCSI 168
25.2.1. iSCSI API 168
25.2.2. iSCSI Target Set up 169
25.3. Persistent Naming 170
25.3.1. WWID 171
25.3.2. UUID and Other Persistent Identifiers 172
25.4. Removing a Storage Device 172
25.5. Removing a Path to a Storage Device 173
25.6. Adding a Storage Device or Path 174
25.7. Configuring a Fibre-Channel Over Ethernet Interface 176
25.7.1. Fibre-Channel over Ethernet (FCoE) Target Set up 177

25.8. Configuring an FCoE Interface to Automatically Mount at Boot 179
25.9. Scanning Storage Interconnects 181
25.10. iSCSI Discovery Configuration 181
25.11. Configuring iSCSI Offload and Interface Binding 182
25.11.1. Viewing Available iface Configurations 183
25.11.2. Configuring an iface for Software iSCSI 184
25.11.3. Configuring an iface for iSCSI Offload 185
25.11.4. Binding/Unbinding an iface to a Portal 185
25.12. Scanning iSCSI Interconnects 186
25.13. Logging in to an iSCSI Target 189
25.14. Resizing an Online Logical Unit 189
25.14.1. Resizing Fibre Channel Logical Units 190
25.14.2. Resizing an iSCSI Logical Unit 190
25.14.3. Updating the Size of Your Multipath Device 191
25.14.4. Changing the Read/Write State of an Online Logical Unit 192
25.14.4.1. Rescanning logical units 193
25.14.4.2. Updating the R/W state of a multipath device 193
25.14.4.3. Documentation 194
25.15. Adding/Removing a Logical Unit Through rescan-scsi-bus.sh 194

Known Issues With rescan-scsi-bus.sh 194
25.16. Modifying Link Loss Behavior 194
25.16.1. Fibre Channel 194
25.16.2. iSCSI Settings With dm-multipath 195
25.16.2.1. NOP-Out Interval/Timeout 195

SCSI Error Handler 196
25.16.2.2. replacement_timeout 196
25.16.3. iSCSI Root 197

Configuring Timeouts for a Specific Session 197
25.17. Controlling the SCSI Command Timer and Device Status 197

Device States 198

Command Timer 198
25.18. Online Storage Configuration Troubleshooting 198

Chapter 26. Device Mapper Multipathing and Virtual Storage 200
26.1. Virtual Storage 200
26.2. DM-Multipath 200

Revision History 202

Index 204

Preface

1. Document Conventions

This manual uses several conventions to highlight certain words and phrases and draw attention to specific pieces of information.

1.1. Typographic Conventions

Four typographic conventions are used to call attention to specific words and phrases. These conventions, and the circumstances they apply to, are as follows.

`Mono-spaced Bold`

Used to highlight system input, including shell commands, file names and paths. Also used to highlight keys and key combinations. For example:

> To see the contents of the file **`my_next_bestselling_novel`** in your current working directory, enter the **`cat my_next_bestselling_novel`** command at the shell prompt and press **`Enter`** to execute the command.

The above includes a file name, a shell command and a key, all presented in mono-spaced bold and all distinguishable thanks to context.

Key combinations can be distinguished from an individual key by the plus sign that connects each part of a key combination. For example:

> Press **`Enter`** to execute the command.
>
> Press **`Ctrl`**+**`Alt`**+**`F2`** to switch to a virtual terminal.

The first example highlights a particular key to press. The second example highlights a key combination: a set of three keys pressed simultaneously.

If source code is discussed, class names, methods, functions, variable names and returned values mentioned within a paragraph will be presented as above, in **`mono-spaced bold`**. For example:

> File-related classes include **`filesystem`** for file systems, **`file`** for files, and **`dir`** for directories. Each class has its own associated set of permissions.

Proportional Bold

This denotes words or phrases encountered on a system, including application names; dialog-box text; labeled buttons; check-box and radio-button labels; menu titles and submenu titles. For example:

> Choose **System** → **Preferences** → **Mouse** from the main menu bar to launch **Mouse Preferences**. In the **Buttons** tab, select the **`Left-handed mouse`** check box and click **`Close`** to switch the primary mouse button from the left to the right (making the mouse suitable for use in the left hand).
>
> To insert a special character into a **`gedit`** file, choose **Applications** → **Accessories** → **Character Map** from the main menu bar. Next, choose **Search** → **Find…** from the **Character Map** menu bar, type the name of the character in the **Search** field and click **`Next`**. The character you sought will be highlighted in the

> **Character Table**. Double-click this highlighted character to place it in the **Text to copy** field and then click the **Copy** button. Now switch back to your document and choose **Edit** → **Paste** from the **gedit** menu bar.

The above text includes application names; system-wide menu names and items; application-specific menu names; and buttons and text found within a GUI interface, all presented in proportional bold and all distinguishable by context.

Mono-spaced Bold Italic or ***Proportional Bold Italic***

Whether mono-spaced bold or proportional bold, the addition of italics indicates replaceable or variable text. Italics denotes text you do not input literally or displayed text that changes depending on circumstance. For example:

> To connect to a remote machine using ssh, type **ssh *username*@*domain.name*** at a shell prompt. If the remote machine is **example.com** and your username on that machine is john, type **ssh john@example.com**.
>
> The **mount -o remount *file-system*** command remounts the named file system. For example, to remount the **/home** file system, the command is **mount -o remount /home**.
>
> To see the version of a currently installed package, use the **rpm -q *package*** command. It will return a result as follows: ***package-version-release***.

Note the words in bold italics above: username, domain.name, file-system, package, version and release. Each word is a placeholder, either for text you enter when issuing a command or for text displayed by the system.

Aside from standard usage for presenting the title of a work, italics denotes the first use of a new and important term. For example:

> Publican is a *DocBook* publishing system.

1.2. Pull-quote Conventions

Terminal output and source code listings are set off visually from the surrounding text.

Output sent to a terminal is set in **mono-spaced roman** and presented thus:

```
books        Desktop   documentation  drafts  mss    photos   stuff  svn
books_tests  Desktop1  downloads      images  notes  scripts  svgs
```

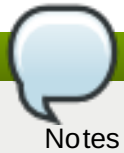
Source-code listings are also set in **mono-spaced roman** but add syntax highlighting as follows:

```
static int kvm_vm_ioctl_deassign_device(struct kvm *kvm,
                  struct kvm_assigned_pci_dev *assigned_dev)
{
         int r = 0;
         struct kvm_assigned_dev_kernel *match;

         mutex_lock(&kvm->lock);

         match = kvm_find_assigned_dev(&kvm->arch.assigned_dev_head,
                                       assigned_dev->assigned_dev_id);
         if (!match) {
                 printk(KERN_INFO "%s: device hasn't been assigned
```

```
before, "
                        "so cannot be deassigned\n", __func__);
                r = -EINVAL;
                goto out;
        }

        kvm_deassign_device(kvm, match);

        kvm_free_assigned_device(kvm, match);

out:
        mutex_unlock(&kvm->lock);
        return r;
}
```

1.3. Notes and Warnings

Finally, we use three visual styles to draw attention to information that might otherwise be overlooked.



Note

Notes are tips, shortcuts or alternative approaches to the task at hand. Ignoring a note should have no negative consequences, but you might miss out on a trick that makes your life easier.

Important

Important boxes detail things that are easily missed: configuration changes that only apply to the current session, or services that need restarting before an update will apply. Ignoring a box labeled “Important” will not cause data loss but may cause irritation and frustration.

Warning

Warnings should not be ignored. Ignoring warnings will most likely cause data loss.

2. Getting Help and Giving Feedback

2.1. Do You Need Help?

If you experience difficulty with a procedure described in this documentation, visit the Red Hat Customer Portal at http://access.redhat.com. From the Customer Portal, you can:

- Search or browse through a knowledge base of technical support articles about Red Hat products.
- Submit a support case to Red Hat Global Support Services (GSS).
- Access other product documentation.

Red Hat also hosts a large number of electronic mailing lists for discussion of Red Hat software and technology. You can find a list of publicly available mailing lists at https://www.redhat.com/mailman/listinfo. Click the name of any mailing list to subscribe to that list or to access the list archives.

2.2. We Need Feedback

If you find a typographical error in this manual, or if you have thought of a way to make this manual better, we would love to hear from you. Please submit a report in Bugzilla: http://bugzilla.redhat.com/ against the product Red Hat Enterprise Linux 6.

When submitting a bug report, be sure to mention the manual's identifier: *doc-Storage_Admin_Guide*

If you have a suggestion for improving the documentation, try to be as specific as possible when describing it. If you have found an error, please include the section number and some of the surrounding text so we can find it easily.

Chapter 1. Overview

The *Storage Administration Guide* contains extensive information on supported file systems and data storage features in Red Hat Enterprise Linux 6. This book is intended as a quick reference for administrators managing single-node (that is, non-clustered) storage solutions.

The Storage Administration Guide is split into two parts: File Systems, and Storage Administration.

The File Systems part details the various file systems Red Hat Enterprise Linux 6 supports. It describes them and explains how best to utilize them.

The Storage Administration part details the various tools and storage administration tasks Red Hat Enterprise Linux 6 supports. It describes them and explains how best to utilize them.

1.1. What's New in Red Hat Enterprise Linux 6

Red Hat Enterprise Linux 6 features the following file system enhancements:

File System Encryption (Technology Preview)

It is now possible to encrypt a file system at mount using *eCryptfs* [1], providing an encryption layer on top of an actual file system. This "pseudo-file system" allows per-file and file name encryption, which offers more granular encryption than encrypted block devices. For more information about file system encryption, refer to Chapter 3, *Encrypted File System*.

File System Caching (Technology Preview)

FS-Cache[1] allows the use of local storage for caching data from file systems served over the network (for example, through NFS). This helps minimize network traffic, although it does not guarantee faster access to data over the network. FS-Cache allows a file system on a server to interact directly with a client's local cache without creating an overmounted file system. For more information about FS-Cache, refer to Chapter 10, *FS-Cache*.

Btrfs (Technology Preview)

Btrfs[1] is a local file system that is now available. It aims to provide better performance and scalability, including integrated LVM operations. For more information on Btrfs, refer to Chapter 4, *Btrfs*.

I/O Limit Processing

The Linux I/O stack can now process I/O limit information for devices that provide it. This allows storage management tools to better optimize I/O for some devices. For more information on this, refer to Chapter 23, *Storage I/O Alignment and Size*.

ext4 Support

The ext4 file system is fully supported in this release. It is now the default file system of Red Hat Enterprise Linux 6, supporting an unlimited number of subdirectories. It also features more granular timestamping, extended attributes support, and quota journaling. For more information on ext4, refer to Chapter 6, *The Ext4 File System*.

Network Block Storage

Fibre-channel over Ethernet is now supported. This allows a fibre-channel interface to use 10-Gigabit Ethernet networks while preserving the fibre-channel protocol. For instructions on how to set this up, refer to Section 25.7, “Configuring a Fibre-Channel Over Ethernet Interface”.

---

[1] This feature is being provided in this release as a *technology preview*. Technology Preview features are currently not supported under Red Hat Enterprise Linux subscription services, may not be functionally complete, and are generally not suitable for production use. However, these features are included as a customer convenience and to provide the feature with wider exposure.

You are free to provide feedback and functionality suggestions for a technology preview feature before it becomes fully supported. Erratas will be provided for high-severity security issues.

Part I. File Systems

The File Systems section explains file system structure followed by two technology previews: eCryptfs and Btrfs. This is followed by the file systems Red Hat fully supports: ext3, ext4, global file system 2, XFS, NFS, and FS-Cache.

Chapter 2. File System Structure and Maintenance

The file system structure is the most basic level of organization in an operating system. The way an operating system interacts with its users, applications, and security model nearly always depends on how the operating system organizes files on storage devices. Providing a common file system structure ensures users and programs can access and write files.

File systems break files down into two logical categories:

- Shareable versus unshareable files
- Variable versus static files

Shareable files can be accessed locally and by remote hosts; *unshareable* files are only available locally. *Variable* files, such as log files, can be changed at any time; *static* files, such as binaries, do not change without an action from the system administrator.

Categorizing files in this manner helps correlate the function of each file with the permissions assigned to the directories which hold them. How the operating system and its users interact with a file determines the directory in which it is placed, whether that directory is mounted with read-only or read/write permissions, and the level of access each user has to that file. The top level of this organization is crucial; access to the underlying directories can be restricted, otherwise security problems could arise if, from the top level down, access rules do not adhere to a rigid structure.

2.1. Overview of Filesystem Hierarchy Standard (FHS)

Red Hat Enterprise Linux uses the *Filesystem Hierarchy Standard* (*FHS*) file system structure, which defines the names, locations, and permissions for many file types and directories.

The FHS document is the authoritative reference to any FHS-compliant file system, but the standard leaves many areas undefined or extensible. This section is an overview of the standard and a description of the parts of the file system not covered by the standard.

The two most important elements of FHS compliance are:

- Compatibility with other FHS-compliant systems
- The ability to mount a **/usr/** partition as read-only. This is especially crucial, since **/usr/** contains common executables and should not be changed by users. In addition, since **/usr/** is mounted as read-only, it should be mountable from the CD-ROM drive or from another machine via a read-only NFS mount.

2.1.1. FHS Organization

The directories and files noted here are a small subset of those specified by the FHS document. Refer to the latest FHS documentation for the most complete information at http://www.pathname.com/fhs/.

2.1.1.1. Gathering File System Information

The **df** command reports the system's disk space usage. Its output looks similar to the following:

Example 2.1. df command output

```
Filesystem           1K-blocks      Used Available Use% Mounted on
/dev/mapper/VolGroup00-LogVol00
```

```
                        11675568   6272120   4810348  57% / /dev/sda1
                  100691      9281     86211  10% /boot
none                         322856         0    322856   0% /dev/shm
```

By default, **df** shows the partition size in 1 kilobyte blocks and the amount of used and available disk space in kilobytes. To view the information in megabytes and gigabytes, use the command **df -h**. The **-h** argument stands for "human-readable" format. The output for **df -h** looks similar to the following:

Example 2.2. df -h command output

```
Filesystem            Size  Used Avail Use% Mounted on
/dev/mapper/VolGroup00-LogVol00
                        12G  6.0G  4.6G  57% / /dev/sda1
   99M  9.1M   85M  10% /boot
none    316M     0  316M   0% /dev/shm
```

Note

In the above examples, the mounted partition **/dev/shm** represents the system's virtual memory file system.

The **du** command displays the estimated amount of space being used by files in a directory, displaying the disk usage of each subdirectory. The last line in the output of **du** shows the total disk usage of the directory; to see only the total disk usage of a directory in human-readable format, use **du -hs**. For more options, refer to **man du**.

To view the system's partitions and disk space usage in a graphical format, use the Gnome **System Monitor** by clicking on **Applications** → **System Tools** → **System Monitor** or using the command **gnome-system-monitor**. Select the **File Systems** tab to view the system's partitions. The figure below illustrates the **File Systems** tab.

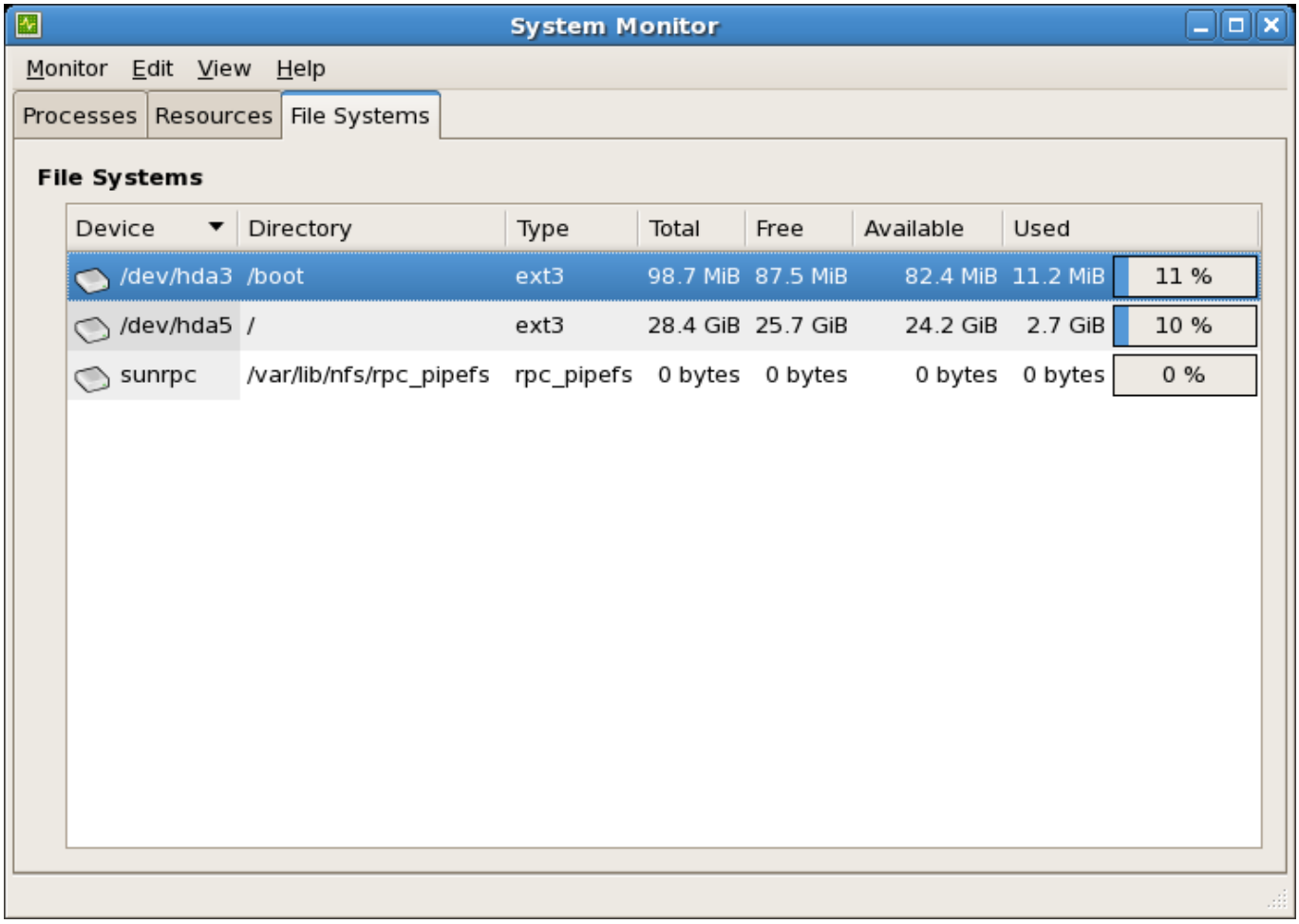

System Monitor
Monitor Edit View Help
Processes Resources File Systems
File Systems
Device Directory Type Total Free Available Used
/dev/hda3 /boot ext3 98.7 MiB 87.5 MiB 82.4 MiB 11.2 MiB 11 %
/dev/hda5 / ext3 28.4 GiB 25.7 GiB 24.2 GiB 2.7 GiB 10 %
sunrpc /var/lib/nfs/rpc_pipefs rpc_pipefs 0 bytes 0 bytes 0 bytes 0 bytes 0 %

Figure 2.1. GNOME System Monitor File Systems tab

2.1.1.2. The `/boot/` Directory

The **`/boot/`** directory contains static files required to boot the system, for example, the Linux kernel. These files are essential for the system to boot properly.

Warning

Do not remove the **`/boot/`** directory. Doing so renders the system unbootable.

2.1.1.3. The `/dev/` Directory

The **`/dev/`** directory contains device nodes that represent the following device types:

- devices attached to the system;
- virtual devices provided by the kernel.

These device nodes are essential for the system to function properly. The **udevd** daemon creates and removes device nodes in **`/dev/`** as needed.

Devices in the **`/dev/`** directory and subdirectories are defined as either *character* (providing only a serial stream of input and output, for example, mouse or keyboard) or *block* (accessible randomly, for example, a hard drive or a floppy drive). If GNOME or KDE is installed, some storage devices are automatically detected when connected (such as with a USB) or inserted (such as a CD or DVD

drive), and a pop-up window displaying the contents appears.

Table 2.1. Examples of common files in the /dev directory

File	Description
/dev/hda	The master device on the primary IDE channel.
/dev/hdb	The slave device on the primary IDE channel.
/dev/tty0	The first virtual console.
/dev/tty1	The second virtual console.
/dev/sda	The first device on the primary SCSI or SATA channel.
/dev/lp0	The first parallel port.
/dev/ttyS0	Serial port.

2.1.1.4. The /etc/ Directory

The **/etc/** directory is reserved for configuration files that are local to the machine. It should contain no binaries; any binaries should be moved to **/bin/** or **/sbin/**.

For example, the **/etc/skel/** directory stores "skeleton" user files, which are used to populate a home directory when a user is first created. Applications also store their configuration files in this directory and may reference them when executed. The **/etc/exports** file controls which file systems export to remote hosts.

2.1.1.5. The /lib/ Directory

The **/lib/** directory should only contain libraries needed to execute the binaries in **/bin/** and **/sbin/**. These shared library images are used to boot the system or execute commands within the root file system.

2.1.1.6. The /media/ Directory

The **/media/** directory contains subdirectories used as mount points for removable media, such as USB storage media, DVDs, and CD-ROMs.

2.1.1.7. The /mnt/ Directory

The **/mnt/** directory is reserved for temporarily mounted file systems, such as NFS file system mounts. For all removable storage media, use the **/media/** directory. Automatically detected removable media will be mounted in the **/media** directory.

Important

The **/mnt** directory must not be used by installation programs.

2.1.1.8. The /opt/ Directory

The **/opt/** directory is normally reserved for software and add-on packages that are not part of the default installation. A package that installs to **/opt/** creates a directory bearing its name, for example **/opt/*packagename*/**. In most cases, such packages follow a predictable subdirectory structure; most store their binaries in **/opt/*packagename*/bin/** and their **man** pages in

/opt/*packagename*/man/.

2.1.1.9. The /proc/ Directory

The **/proc/** directory contains special files that either extract information from the kernel or send information to it. Examples of such information include system memory, CPU information, and hardware configuration. For more information about **/proc/**, refer to Section 2.3, “The /proc Virtual File System”.

2.1.1.10. The /sbin/ Directory

The **/sbin/** directory stores binaries essential for booting, restoring, recovering, or repairing the system. The binaries in **/sbin/** require root privileges to use. In addition, **/sbin/** contains binaries used by the system *before* the **/usr/** directory is mounted; any system utilities used after **/usr/** is mounted are typically placed in **/usr/sbin/**.

At a minimum, the following programs should be stored in **/sbin/**:

- **arp**
- **clock**
- **halt**
- **init**
- **fsck.***
- **grub**
- **ifconfig**
- **mingetty**
- **mkfs.***
- **mkswap**
- **reboot**
- **route**
- **shutdown**
- **swapoff**
- **swapon**

2.1.1.11. The /srv/ Directory

The **/srv/** directory contains site-specific data served by a Red Hat Enterprise Linux system. This directory gives users the location of data files for a particular service, such as FTP, WWW, or CVS. Data that only pertains to a specific user should go in the **/home/** directory.

Note

The default httpd install uses **/var/www/html** for served content.

2.1.1.12. The /sys/ Directory

The **/sys/** directory utilizes the new **sysfs** virtual file system specific to the 2.6 kernel. With the increased support for hot plug hardware devices in the 2.6 kernel, the **/sys/** directory contains information similar to that held by **/proc/**, but displays a hierarchical view of device information specific to hot plug devices.

2.1.1.13. The /usr/ Directory

The **/usr/** directory is for files that can be shared across multiple machines. The **/usr/** directory is often on its own partition and is mounted read-only. The **/usr/** directory usually contains the following subdirectories:

/usr/bin

This directory is used for binaries.

/usr/etc

This directory is used for system-wide configuration files.

/usr/games

This directory stores games.

/usr/include

This directory is used for C header files.

/usr/kerberos

This directory is used for Kerberos-related binaries and files.

/usr/lib

This directory is used for object files and libraries that are not designed to be directly utilized by shell scripts or users. This directory is for 32-bit systems.

/usr/lib64

This directory is used for object files and libraries that are not designed to be directly utilized by shell scripts or users. This directory is for 64-bit systems.

/usr/libexec

This directory contains small helper programs called by other programs.

/usr/sbin

This directory stores system administration binaries that do not belong to **/sbin/**.

/usr/share

This directory stores files that are not architecture-specific.

/usr/src

This directory stores source code.

/usr/tmp linked to /var/tmp

This directory stores temporary files.

The **/usr/** directory should also contain a **/local/** subdirectory. As per the FHS, this subdirectory is used by the system administrator when installing software locally, and should be safe from being overwritten during system updates. The **/usr/local** directory has a structure similar to **/usr/**, and contains the following subdirectories:

- **/usr/local/bin**
- **/usr/local/etc**
- **/usr/local/games**
- **/usr/local/include**
- **/usr/local/lib**
- **/usr/local/libexec**
- **/usr/local/sbin**
- **/usr/local/share**
- **/usr/local/src**

Red Hat Enterprise Linux's usage of **/usr/local/** differs slightly from the FHS. The FHS states that **/usr/local/** should be used to store software that should remain safe from system software upgrades. Since the **RPM Package Manager** can perform software upgrades safely, it is not necessary to protect files by storing them in **/usr/local/**.

Instead, Red Hat Enterprise Linux uses **/usr/local/** for software local to the machine. For instance, if the **/usr/** directory is mounted as a read-only NFS share from a remote host, it is still possible to install a package or program under the **/usr/local/** directory.

2.1.1.14. The /var/ Directory

Since the FHS requires Linux to mount **/usr/** as read-only, any programs that write log files or need **spool/** or **lock/** directories should write them to the **/var/** directory. The FHS states **/var/** is for variable data, which includes spool directories and files, logging data, transient and temporary files.

Below are some of the directories found within the **/var/** directory depending on what is installed on the system:

- **/var/account/**
- **/var/arpwatch/**
- **/var/cache/**
- **/var/crash/**
- **/var/db/**
- **/var/empty/**

- **/var/ftp/**
- **/var/gdm/**
- **/var/kerberos/**
- **/var/lib/**
- **/var/local/**
- **/var/lock/**
- **/var/log/**
- **/var/mail** linked to **/var/spool/mail/**
- **/var/mailman/**
- **/var/named/**
- **/var/nis/**
- **/var/opt/**
- **/var/preserve/**
- **/var/run/**
- **/var/spool/**
- **/var/tmp/**
- **/var/tux/**
- **/var/www/**
- **/var/yp/**

System log files, such as **messages** and **lastlog**, go in the **/var/log/** directory. The **/var/lib/rpm/** directory contains RPM system databases. Lock files go in the **/var/lock/** directory, usually in directories for the program using the file. The **/var/spool/** directory has subdirectories that store data files for some programs. These subdirectories may include:

- **/var/spool/at/**
- **/var/spool/clientmqueue/**
- **/var/spool/cron/**
- **/var/spool/cups/**
- **/var/spool/exim/**
- **/var/spool/lpd/**
- **/var/spool/mail/**
- **/var/spool/mailman/**
- **/var/spool/mqueue/**
- **/var/spool/news/**

- **/var/spool/postfix/**
- **/var/spool/repackage/**
- **/var/spool/rwho/**
- **/var/spool/samba/**
- **/var/spool/squid/**
- **/var/spool/squirrelmail/**
- **/var/spool/up2date/**
- **/var/spool/uucp/**
- **/var/spool/uucppublic/**
- **/var/spool/vbox/**

2.2. Special Red Hat Enterprise Linux File Locations

Red Hat Enterprise Linux extends the FHS structure slightly to accommodate special files.

Most files pertaining to RPM are kept in the **/var/lib/rpm/** directory. For more information on RPM, refer to **man rpm**.

The **/var/cache/yum/** directory contains files used by the **Package Updater**, including RPM header information for the system. This location may also be used to temporarily store RPMs downloaded while updating the system. For more information about the Red Hat Network, refer to the documentation online at https://rhn.redhat.com/.

Another location specific to Red Hat Enterprise Linux is the **/etc/sysconfig/** directory. This directory stores a variety of configuration information. Many scripts that run at boot time use the files in this directory.

2.3. The /proc Virtual File System

Unlike most file systems, **/proc** contains neither text nor binary files. Instead, it houses *virtual files*; as such, **/proc** is normally referred to as a virtual file system. These virtual files are typically zero bytes in size, even if they contain a large amount of information.

The **/proc** file system is not used for storage. Its main purpose is to provide a file-based interface to hardware, memory, running processes, and other system components. Real-time information can be retrieved on many system components by viewing the corresponding **/proc** file. Some of the files within **/proc** can also be manipulated (by both users and applications) to configure the kernel.

The following **/proc** files are relevant in managing and monitoring system storage:

/proc/devices

Displays various character and block devices that are currently configured.

/proc/filesystems

Lists all file system types currently supported by the kernel.

/proc/mdstat

Contains current information on multiple-disk or RAID configurations on the system, if they exist.

/proc/mounts

Lists all mounts currently used by the system.

/proc/partitions

Contains partition block allocation information.

For more information about the **/proc** file system, refer to the Red Hat Enterprise Linux 6 *Deployment Guide*.

2.4. Discard unused blocks

Batch discard and online discard operations are features of mounted file systems that discard blocks not in use by the file system. They are useful for both solid-state drives and thinly-provisioned storage.

Batch discard operations are run explicitly by the user with the **fstrim** command. This command discards all unused blocks in a file system that match the user's criteria. Both operation types are supported for use with ext4 file systems as of Red Hat Enterprise Linux 6.2 and later, so long as the block device underlying the file system supports physical discard operations. This is also the case with XFS file systems as of Red Hat Enterprise Linux 6.4 and later. Physical discard operations are supported if the value of **/sys/block/*device*/queue/discard_max_bytes** is not zero.

Online discard operations are specified at mount time with the **-o discard** option (either in **/etc/fstab** or as part of the **mount** command), and run in realtime without user intervention. Online discard operations only discard blocks that are transitioning from used to free. Online discard operations are supported on ext4 file systems as of Red Hat Enterprise Linux 6.2 and later, and on XFS file systems as of Red Hat Enterprise Linux 6.4 and later.

Red Hat recommends batch discard operations unless the system's workload is such that batch discard is not feasible, or online discard operations are necessary to maintain performance.

Chapter 3. Encrypted File System

Red Hat Enterprise Linux 6 provides a technology preview of *eCryptfs*, a "pseudo-file system" which provides data and filename encryption on a per-file basis. The term "pseudo-file system" refers to the fact that eCryptfs does not have an on-disk format; rather, it is a file system layer that resides on top of an actual file system. The eCryptfs layer provides encryption capabilities.

eCryptfs works like a bind mount by intercepting file operations that write to the underlying (that is, encrypted) file system. The eCryptfs layer adds a header to the metadata of files in the underlying file system. This metadata describes the encryption for that file, and eCryptfs encrypts file data before it is passed to the encrypted file system. Optionally, eCryptfs can also encrypt filenames.

eCryptfs is not an on-disk file system; as such, there is no need to create it via tools such as **mkfs**. Instead, eCryptfs is initiated by issuing a special mount command. To manage file systems protected by eCryptfs, the **ecryptfs-utils** package must be installed first.

3.1. Mounting a File System as Encrypted

To encrypt a file system with eCryptfs, execute the following command:

```
# mount -t ecryptfs /source /destination
```

Encrypting a directory hierarchy (***/source*** in the above example) with eCryptfs means mounting it to a mount point encrypted by eCryptfs (***/destination*** in the example above). All file operations to ***/destination*** will be passed encrypted to the underlying ***/source*** file system. In some cases, however, it may be possible for a file operation to modify ***/source*** directly without passing through the eCryptfs layer; this could lead to inconsistencies.

This is why for most environments, Red Hat recommends that the names of both ***/source*** and ***/destination*** be identical. For example:

```
# mount -t ecryptfs /home /home
```

This effectively means encrypting a file system and mounting it *on itself*. Doing so helps ensure that *all* file operations to **/home** pass through the eCryptfs layer.

During the mount and encryption process, **mount** will allow the following settings to be configured:

Encryption key type

openssl, **tspi**, or **passphrase**. When choosing **passphrase**, **mount** will ask for one.

Cipher

aes, **blowfish**, **des3_ede**, **cast6**, or **cast5**.

Key bytesize

16, **32**, or **24**.

plaintext passthrough

Enabled or disabled.

filename encryption

Enabled or disabled.

After the last step of an interactive mount, **mount** will display all the selections made and perform the mount. This output consists of the command-line option equivalents of each chosen setting. For example, mounting **/home** with a key type of **passphrase**, **aes** cipher, key bytesize of **16** with both **plaintext passthrough** and **filename encryption** disabled, the output would be:

```
Attempting to mount with the following options:
  ecryptfs_unlink_sigs
  ecryptfs_key_bytes=16
  ecryptfs_cipher=aes
  ecryptfs_sig=c7fed37c0a341e19
Mounted eCryptfs
```

The options in this display can then be passed directly to the command line to encrypt and mount a file system using the same configuration. To do so, use each option as an argument to the **-o** option of **mount**. For example:

```
# mount -t ecryptfs /home /home -o ecryptfs_unlink_sigs \
 ecryptfs_key_bytes=16 ecryptfs_cipher=aes ecryptfs_sig=c7fed37c0a341e19
      [2]
```

3.2. Additional Information

For more information on eCryptfs and its mount options, refer to **man ecryptfs** (provided by the **ecryptfs-utils** package). The following Kernel document (provided by the **kernel-doc** package) also provides additional information on eCryptfs:

/usr/share/doc/kernel-doc-*version*/Documentation/filesystems/ecryptfs.txt

[2] This is a single command split into multiple lines, to accommodate printed and PDF versions of this document. All concatenated lines — preceded by the backslash (\) — should be treated as one command, sans backslashes.

Chapter 4. Btrfs

Btrfs is a new local file system under active development. It aims to provide better performance and scalability which will in turn benefit users.

Note

Btrfs is not a production quality file system at this point. With Red Hat Enterprise Linux 6 it is at a technology preview stage and as such is only being built for Intel 64 and AMD64.

4.1. Btrfs Features

Several utilities are built in to Btrfs to provide ease of administration for system administrators. These include:

Built-in System Rollback

File system snapshots make it possible to roll a system back to a prior, known-good state if something goes wrong.

Built-in Compression

This makes saving space easier.

Checksum Functionality

This improves error detection.

Specific features include integrated LVM operations, such as:

- dynamic, online addition or removal of new storage devices
- internal support for RAID across the component devices
- the ability to use different RAID levels for meta or user data
- full checksum functionality for all meta and user data.

Chapter 5. The Ext3 File System

The ext3 file system is essentially an enhanced version of the ext2 file system. These improvements provide the following advantages:

Availability

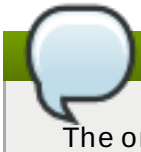
After an unexpected power failure or system crash (also called an *unclean system shutdown*), each mounted ext2 file system on the machine must be checked for consistency by the **e2fsck** program. This is a time-consuming process that can delay system boot time significantly, especially with large volumes containing a large number of files. During this time, any data on the volumes is unreachable.

It is possible to run **fsck -n** on a live filesystem. However, it will not make any changes and may give misleading results if partially written metadata is encountered.

If LVM is used in the stack, another option is to take an LVM snapshot of the filesystem and run **fsck** on it instead.

Finally, there is the option to remount the filesystem as read only. All pending metadata updates (and writes) are then forced to the disk prior to the remount. This ensures the filesystem is in a consistent state, provided there is no previous corruption. It is now possible to run **fsck -n**.

The journaling provided by the ext3 file system means that this sort of file system check is no longer necessary after an unclean system shutdown. The only time a consistency check occurs using ext3 is in certain rare hardware failure cases, such as hard drive failures. The time to recover an ext3 file system after an unclean system shutdown does not depend on the size of the file system or the number of files; rather, it depends on the size of the *journal* used to maintain consistency. The default journal size takes about a second to recover, depending on the speed of the hardware.



Note

The only journaling mode in ext3 supported by Red Hat is **data=ordered** (default).

Data Integrity

The ext3 file system prevents loss of data integrity in the event that an unclean system shutdown occurs. The ext3 file system allows you to choose the type and level of protection that your data receives. With regard to the state of the file system, ext3 volumes are configured to keep a high level of data consistency by default.

Speed

Despite writing some data more than once, ext3 has a higher throughput in most cases than ext2 because ext3's journaling optimizes hard drive head motion. You can choose from three journaling modes to optimize speed, but doing so means trade-offs in regards to data integrity if the system was to fail.

Easy Transition

It is easy to migrate from ext2 to ext3 and gain the benefits of a robust journaling file system without reformatting. Refer to Section 5.2, “Converting to an Ext3 File System” for more information on how to perform this task.

The Red Hat Enterprise Linux 6 version of ext3 features the following updates:

Default Inode Sizes Changed

The default size of the on-disk inode has increased for more efficient storage of extended attributes, for example, ACLs or SELinux attributes. Along with this change, the default number of inodes created on a file system of a given size has been decreased. The inode size may be selected with the **mke2fs -I** option or specified in **/etc/mke2fs.conf** to set system wide defaults for **mke2fs**.

Note

If you upgrade to Red Hat Enterprise Linux 6 with the intention of keeping any ext3 file systems intact, there is no need to remake the file system.

New Mount Option: data_err

A new mount option has been added: **data_err=abort**. This option instructs ext3 to abort the journal if an error occurs in a file data (as opposed to metadata) buffer in **data=ordered** mode. This option is disabled by default (set as **data_err=ignore**).

More Efficient Storage Use

When creating a file system (that is, **mkfs**), **mke2fs** will attempt to "discard" or "trim" blocks not used by the file system metadata. This helps to optimize SSDs or thinly-provisioned storage. To suppress this behavior, use the **mke2fs -K** option.

The following sections cover creating and tuning ext3 partitions. For ext2 partitions, skip the partitioning and formatting sections below and go directly to Section 5.2, “Converting to an Ext3 File System”.

5.1. Creating an Ext3 File System

After installation, it is sometimes necessary to create a new ext3 file system. For example, if a new disk drive is added to the system, you may want to partition the drive and use the ext3 file system.

The steps for creating an ext3 file system are as follows:

Procedure 5.1. Create an ext3 file system

1. Format the partition with the ext3 file system using **mkfs**.
2. Label the file system using **e2label**.

5.2. Converting to an Ext3 File System

The **tune2fs** command converts an **ext2** file system to **ext3**.

Note

A default installation of Red Hat Enterprise Linux uses ext4 for all file systems. However, to convert ext2 to ext3, always use the **e2fsck** utility to check your file system before and after using **tune2fs**. Before trying to convert ext2 to ext3, back up all file systems in case any errors occur.

In addition, Red Hat recommends creating a new ext3 file system and migrating data to it, instead of converting from ext2 to ext3 whenever possible.

To convert an **ext2** file system to **ext3**, log in as root and type the following command in a terminal:

```
# tune2fs -j block_device
```

block_device contains the ext2 file system to be converted.

A valid block device can be one of two types of entries:

A mapped device

A logical volume in a volume group, for example, **/dev/mapper/VolGroup00-LogVol02**.

A static device

A traditional storage volume, for example, **/dev/*sdbX***, where *sdb* is a storage device name and *X* is the partition number.

Issue the **df** command to display mounted file systems.

5.3. Reverting to an Ext2 File System

In order to revert to an ext2 file system, use the following procedure.

For simplicity, the sample commands in this section use the following value for the block device:

/dev/mapper/VolGroup00-LogVol02

Procedure 5.2. Revert from ext3 to ext2

1. Unmount the partition by logging in as root and typing:

```
# umount /dev/mapper/VolGroup00-LogVol02
```

2. Change the file system type to ext2 by typing the following command:

```
# tune2fs -O ^has_journal /dev/mapper/VolGroup00-LogVol02
```

3. Check the partition for errors by typing the following command:

```
# e2fsck -y /dev/mapper/VolGroup00-LogVol02
```

4. Then mount the partition again as ext2 file system by typing:

```
# mount -t ext2 /dev/mapper/VolGroup00-LogVol02 /mount/point
```

In the above command, replace */mount/point* with the mount point of the partition.

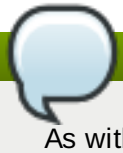
Note

If a **.journal** file exists at the root level of the partition, delete it.

To permanently change the partition to ext2, remember to update the **/etc/fstab** file, otherwise it will revert back after booting.

Chapter 6. The Ext4 File System

The ext4 file system is a scalable extension of the ext3 file system, which was the default file system of Red Hat Enterprise Linux 5. Ext4 is the default file system of Red Hat Enterprise Linux 6, and can support files and file systems up to 16 terabytes in size. It also supports an unlimited number of sub-directories (the ext3 file system only supports up to 32,000), though once the link count exceeds 65,000 it resets to 1 and is no longer increased.



Note

As with ext3, an ext4 volume must be umounted in order to perform an **fsck**. For more information, see Chapter 5, *The Ext3 File System*.

Main Features

Ext4 uses extents (as opposed to the traditional block mapping scheme used by ext2 and ext3), which improves performance when using large files and reduces metadata overhead for large files. In addition, ext4 also labels unallocated block groups and inode table sections accordingly, which allows them to be skipped during a file system check. This makes for quicker file system checks, which becomes more beneficial as the file system grows in size.

Allocation Features

The ext4 file system features the following allocation schemes:

- Persistent pre-allocation
- Delayed allocation
- Multi-block allocation
- Stripe-aware allocation

Because of delayed allocation and other performance optimizations, ext4's behavior of writing files to disk is different from ext3. In ext4, when a program writes to the file system, it is not guaranteed to be on-disk unless the program issues an **fsync()** call afterwards.

By default, ext3 automatically forces newly created files to disk almost immediately even without **fsync()**. This behavior hid bugs in programs that did not use **fsync()** to ensure that written data was on-disk. The ext4 file system, on the other hand, often waits several seconds to write out changes to disk, allowing it to combine and reorder writes for better disk performance than ext3.

Warning

Unlike ext3, the ext4 file system does not force data to disk on transaction commit. As such, it takes longer for buffered writes to be flushed to disk. As with any file system, use data integrity calls such as **fsync()** to ensure that data is written to permanent storage.

Other Ext4 Features

The ext4 file system also supports the following:

- *Extended attributes* (**xattr**) — This allows the system to associate several additional name and value pairs per file.
- *Quota journaling* — This avoids the need for lengthy quota consistency checks after a crash.

Note

The only supported journaling mode in ext4 is **data=ordered** (default).

- *Subsecond timestamps* — This gives timestamps to the subsecond.

6.1. Creating an Ext4 File System

To create an ext4 file system, use the **mkfs.ext4** command. In general, the default options are optimal for most usage scenarios:

```
# mkfs.ext4 /dev/device
```

Below is a sample output of this command, which displays the resulting file system geometry and features:

Example 6.1. mkfs.ext4 command output

```
~]# mkfs.ext4 /dev/sdb1
mke2fs 1.41.12 (17-May-2010)
Filesystem label=
OS type: Linux
Block size=4096 (log=2)
Fragment size=4096 (log=2)
Stride=0 blocks, Stripe width=0 blocks
245280 inodes, 979456 blocks
48972 blocks (5.00%) reserved for the super user
First data block=0
Maximum filesystem blocks=1006632960
30 block groups
32768 blocks per group, 32768 fragments per group
8176 inodes per group
Superblock backups stored on blocks:
 32768, 98304, 163840, 229376, 294912, 819200, 884736

Writing inode tables: done
Creating journal (16384 blocks): done
Writing superblocks and filesystem accounting information: done

This filesystem will be automatically checked every 20 mounts or
180 days, whichever comes first.  Use tune2fs -c or -i to override.
```

For striped block devices (for example, RAID5 arrays), the stripe geometry can be specified at the time of file system creation. Using proper stripe geometry greatly enhances the performance of an ext4 file system.

When creating file systems on LVM or MD volumes, **mkfs.ext4** chooses an optimal geometry. This may also be true on some hardware RAIDs which export geometry information to the operating system.

To specify stripe geometry, use the **-E** option of **mkfs.ext4** (that is, extended file system options) with the following sub-options:

stride=*value*

Specifies the RAID chunk size.

stripe-width=*value*

Specifies the number of data disks in a RAID device, or the number of stripe units in the stripe.

For both sub-options, ***value*** must be specified in file system block units. For example, to create a file system with a 64k stride (that is, 16 x 4096) on a 4k-block file system, use the following command:

```
# mkfs.ext4 -E stride=16,stripe-width=64 /dev/device
```

For more information about creating file systems, refer to **man mkfs.ext4**.

Important

It is possible to use **tune2fs** to enable some ext4 features on ext3 file systems, and to use the ext4 driver to mount an ext3 file system. These actions, however, are *not* supported in Red Hat Enterprise Linux 6, as they have not been fully tested. Because of this, Red Hat cannot guarantee consistent performance and predictable behavior for ext3 file systems converted or mounted in this way.

6.2. Mounting an Ext4 File System

An ext4 file system can be mounted with no extra options. For example:

```
# mount /dev/device /mount/point
```

The ext4 file system also supports several mount options to influence behavior. For example, the **acl** parameter enables access control lists, while the **user_xattr** parameter enables user extended attributes. To enable both options, use their respective parameters with **-o**, as in:

```
# mount -o acl,user_xattr /dev/device /mount/point
```

The **tune2fs** utility also allows administrators to set default mount options in the file system superblock. For more information on this, refer to **man tune2fs**.

Write Barriers

By default, ext4 uses write barriers to ensure file system integrity even when power is lost to a device with write caches enabled. For devices without write caches, or with battery-backed write caches, disable barriers using the **nobarrier** option, as in:

```
# mount -o nobarrier /dev/device /mount/point
```

For more information about write barriers, refer to Chapter 22, *Write Barriers*.

6.3. Resizing an Ext4 File System

Before growing an ext4 file system, ensure that the underlying block device is of an appropriate size to hold the file system later. Use the appropriate resizing methods for the affected block device.

An ext4 file system may be grown while mounted using the **resize2fs** command:

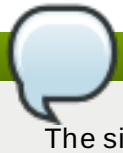
```
# resize2fs /mount/device node
```

The **resize2fs** command can also decrease the size of an *unmounted* ext4 file system:

```
# resize2fs /dev/device size
```

When resizing an ext4 file system, the **resize2fs** utility reads the size in units of file system block size, unless a suffix indicating a specific unit is used. The following suffixes indicate specific units:

- **s** — 512 byte sectors
- **K** — kilobytes
- **M** — megabytes
- **G** — gigabytes



Note

The size parameter is optional (and often redundant) when expanding. The **resize2fs** automatically expands to fill all available space of the container, usually a logical volume or partition.

For more information about resizing an ext4 file system, refer to **man resize2fs**.

6.4. Backup ext2/3/4 File Systems

Procedure 6.1. Backup ext2/3/4 File Systems Example

1. All data must be backed up before attempting any kind of restore operation. Data backups should be made on a regular basis. In addition to data, there is configuration information that should be saved, including **/etc/fstab** and the output of **fdisk -l**. Running an sosreport/sysreport will capture this information and is strongly recommended.

```
# cat /etc/fstab
LABEL=/           /               ext3    defaults        1 1
LABEL=/boot1      /boot           ext3    defaults        1 2
```

```
LABEL=/data         /data            ext3    defaults         0 0
tmpfs               /dev/shm         tmpfs   defaults         0 0
devpts              /dev/pts         devpts  gid=5,mode=620   0 0
sysfs               /sys             sysfs   defaults         0 0
proc                /proc            proc    defaults         0 0
LABEL=SWAP-sda5     swap             swap    defaults         0 0
/dev/sda6           /backup-files    ext3    defaults         0 0

# fdisk -l
   Device Boot     Start       End     Blocks      Id  System
/dev/sda1 *           1        13     104391      83  Linux
/dev/sda2            14      1925   15358140      83  Linux
/dev/sda3          1926      3200   10241437+     83  Linux
/dev/sda4          3201      4864   13366080      5   Extended
/dev/sda5          3201      3391   1534176       82  Linux swap /
Solaris
/dev/sda6          3392      4864   11831841      83  Linux
```

In this example, we will use the **/dev/sda6** partition to save backup files, and we assume that **/dev/sda6** is mounted on **/backup-files**.

2. If the partition being backed up is an operating system partition, bootup your system into Single User Mode. This step is not necessary for normal data partitions.

3. Use **dump** to backup the contents of the partitions:

Note

- If the system has been running for a long time, it is advisable to run **e2fsck** on the partitions before backup.
- **dump** should not be used on heavily loaded and mounted filesystem as it could backup corrupted version of files. This problem has been mentioned on dump.sourceforge.net.

Important

When backing up operating system partitions, the partition must be unmounted.

While it is possible to back up an ordinary data partition while it is mounted, it is adviseable to unmount it where possible. The results of attempting to back up a mounted data partition can be unpredicteable.

```
# dump -0uf /backup-files/sda1.dump /dev/sda1
# dump -0uf /backup-files/sda2.dump /dev/sda2
# dump -0uf /backup-files/sda3.dump /dev/sda3
```

If you want to do a remote backup, you can use both ssh or configure a non-password login.

Note

If using standard redirection, the '-f' option must be passed separately.

```
# dump -0u -f - /dev/sda1 | ssh root@remoteserver.example.com dd
of=/tmp/sda1.dump
```

6.5. Restore an ext2/3/4 File System

Procedure 6.2. Restore an ext2/3/4 File System Example

1. If you are restoring an operating system partition, bootup your system into Rescue Mode. This step is not required for ordinary data partitions.
2. Rebuild sda1/sda2/sda3/sda4/sda5 by using the **fdisk** command.

Note

If necessary, create the partitions to contain the restored file systems. The new partitions must be large enough to contain the restored data. It is important to get the start and end numbers right; these are the starting and ending sector numbers of the partitions.

3. Format the destination partitions by using the **mkfs** command, as shown below.

Important

DO NOT format **/dev/sda6** in the above example because it saves backup files.

```
# mkfs.ext3 /dev/sda1
# mkfs.ext3 /dev/sda2
# mkfs.ext3 /dev/sda3
```

4. If creating new partitions, re-label all the partitions so they match the **fstab** file. This step is not required if the partitions are not being recreated.

```
# e2label /dev/sda1 /boot1
# e2label /dev/sda2 /
# e2label /dev/sda3 /data
# mkswap -L SWAP-sda5 /dev/sda5
```

5. Prepare the working directories.

```
# mkdir /mnt/sda1
# mount -t ext3 /dev/sda1 /mnt/sda1
# mkdir /mnt/sda2
# mount -t ext3 /dev/sda2 /mnt/sda2
```

```
# mkdir /mnt/sda3
# mount -t ext3 /dev/sda3 /mnt/sda3
# mkdir /backup-files
# mount -t ext3 /dev/sda6 /backup-files
```

6. Restore the data.

```
# cd /mnt/sda1
# restore -rf /backup-files/sda1.dump
# cd /mnt/sda2
# restore -rf /backup-files/sda2.dump
# cd /mnt/sda3
# restore -rf /backup-files/sda3.dump
```

If you want to restore from a remote host or restore from a backup file on a remote host you can use either ssh or rsh. You will need to configure a password-less login for the following examples:

Login into 10.0.0.87, and restore sda1 from local sda1.dump file:

```
# ssh 10.0.0.87 "cd /mnt/sda1 && cat /backup-files/sda1.dump |
restore -rf -"
```

Login into 10.0.0.87, and restore sda1 from a remote 10.66.0.124 sda1.dump file:

```
# ssh 10.0.0.87 "cd /mnt/sda1 && RSH=/usr/bin/ssh restore -r -f
10.66.0.124:/tmp/sda1.dump"
```

7. Reboot.

6.6. Other Ext4 File System Utilities

Red Hat Enterprise Linux 6 also features other utilities for managing ext4 file systems:

e2fsck

Used to repair an ext4 file system. This tool checks and repairs an ext4 file system more efficiently than ext3, thanks to updates in the ext4 disk structure.

e2label

Changes the label on an ext4 file system. This tool also works on ext2 and ext3 file systems.

quota

Controls and reports on disk space (blocks) and file (inode) usage by users and groups on an ext4 file system. For more information on using **quota**, refer to **man quota** and Section 16.1, “Configuring Disk Quotas”.

As demonstrated in Section 6.2, “Mounting an Ext4 File System”, the **tune2fs** utility can also adjust configurable file system parameters for ext2, ext3, and ext4 file systems. In addition, the following tools are also useful in debugging and analyzing ext4 file systems:

debugfs

Debugs ext2, ext3, or ext4 file systems.

e2image

Saves critical ext2, ext3, or ext4 file system metadata to a file.

For more information about these utilities, refer to their respective **man** pages.

Chapter 7. Global File System 2

The Red Hat Global File System 2 (GFS2) is a native file system that interfaces directly with the Linux kernel file system interface (VFS layer). When implemented as a cluster file system, GFS2 employs distributed metadata and multiple journals.

GFS2 is based on 64-bit architecture, which can theoretically accommodate an 8 exabyte file system. However, the current supported maximum size of a GFS2 file system is 100 TB. If a system requires GFS2 file systems larger than 100 TB, contact your Red Hat service representative.

When determining the size of a file system, consider its recovery needs. Running the **fsck** command on a very large file system can take a long time and consume a large amount of memory. Additionally, in the event of a disk or disk-subsystem failure, recovery time is limited by the speed of backup media.

When configured in a Red Hat Cluster Suite, Red Hat GFS2 nodes can be configured and managed with Red Hat Cluster Suite configuration and management tools. Red Hat GFS2 then provides data sharing among GFS2 nodes in a Red Hat cluster, with a single, consistent view of the file system name space across the GFS2 nodes. This allows processes on different nodes to share GFS2 files in the same way that processes on the same node can share files on a local file system, with no discernible difference. For information about the Red Hat Cluster Suite, refer to Red Hat's *Cluster Administration* guide.

A GFS2 must be built on a logical volume (created with LVM) that is a linear or mirrored volume. Logical volumes created with LVM in a Red Hat Cluster suite are managed with CLVM (a cluster-wide implementation of LVM), enabled by the CLVM daemon **clvmd**, and running in a Red Hat Cluster Suite cluster. The daemon makes it possible to use LVM2 to manage logical volumes across a cluster, allowing all nodes in the cluster to share the logical volumes. For information on the Logical Volume Manager, see Red Hat's *Logical Volume Manager Administration* guide.

The **gfs2.ko** kernel module implements the GFS2 file system and is loaded on GFS2 cluster nodes.

For comprehensive information on the creation and configuration of GFS2 file systems in clustered and non-clustered storage, refer to Red Hat's *Global File System 2* guide.

Chapter 8. The XFS File System

XFS is a highly scalable, high-performance file system which was originally designed at Silicon Graphics, Inc. It was created to support extremely large filesystems (up to 16 exabytes), files (8 exabytes) and directory structures (tens of millions of entries).

Main Features

XFS supports *metadata journaling*, which facilitates quicker crash recovery. The XFS file system can also be defragmented and enlarged while mounted and active. In addition, Red Hat Enterprise Linux 6 supports backup and restore utilities specific to XFS.

Allocation Features

XFS features the following allocation schemes:

- Extent-based allocation
- Stripe-aware allocation policies
- Delayed allocation
- Space pre-allocation

Delayed allocation and other performance optimizations affect XFS the same way that they do ext4. Namely, a program's writes to an XFS file system are not guaranteed to be on-disk unless the program issues an **`fsync()`** call afterwards.

For more information on the implications of delayed allocation on a file system, refer to *Allocation Features* in Chapter 6, *The Ext4 File System*. The workaround for ensuring writes to disk applies to XFS as well.

Other XFS Features

The XFS file system also supports the following:

***Extended attributes* (`xattr`)**

This allows the system to associate several additional name/value pairs per file.

Quota journaling

This avoids the need for lengthy quota consistency checks after a crash.

Project/directory quotas

This allows quota restrictions over a directory tree.

Subsecond timestamps

This allows timestamps to go to the subsecond.

8.1. Creating an XFS File System

To create an XFS file system, use the **`mkfs.xfs /dev/`*`device`*** command. In general, the default options are optimal for common use.

When using **`mkfs.xfs`** on a block device containing an existing file system, use the **`-f`** option to force an overwrite of that file system.

Example 8.1. `mkfs.xfs` command output

Below is a sample output of the **`mkfs.xfs`** command:

```
meta-data=/dev/device            isize=256    agcount=4, agsize=3277258
blks
         =                       sectsz=512   attr=2
data     =                       bsize=4096   blocks=13109032,
imaxpct=25
         =                       sunit=0      swidth=0 blks
naming   =version 2              bsize=4096   ascii-ci=0
log      =internal log           bsize=4096   blocks=6400, version=2
         =                       sectsz=512   sunit=0 blks, lazy-
count=1
realtime =none                   extsz=4096   blocks=0, rtextents=0
```

Note

After an XFS file system is created, its size cannot be reduced. However, it can still be enlarged using the **`xfs_growfs`** command (refer to Section 8.4, “Increasing the Size of an XFS File System”).

For striped block devices (for example, RAID5 arrays), the stripe geometry can be specified at the time of file system creation. Using proper stripe geometry greatly enhances the performance of an XFS filesystem.

When creating filesystems on LVM or MD volumes, **`mkfs.xfs`** chooses an optimal geometry. This may also be true on some hardware RAIDs that export geometry information to the operating system.

To specify stripe geometry, use the following **`mkfs.xfs`** sub-options:

`su=`*value*

Specifies a stripe unit or RAID chunk size. The ***`value`*** must be specified in bytes, with an optional **`k`**, **`m`**, or **`g`** suffix.

`sw=`*value*

Specifies the number of data disks in a RAID device, or the number of stripe units in the stripe.

The following example specifies a chunk size of 64k on a RAID device containing 4 stripe units:

```
# mkfs.xfs -d su=64k,sw=4 /dev/device
```

For more information about creating XFS file systems, refer to **`man mkfs.xfs`**.

8.2. Mounting an XFS File System

An XFS file system can be mounted with no extra options, for example:

```
# mount /dev/device /mount/point
```

XFS also supports several mount options to influence behavior.

XFS allocates inodes to reflect their on-disk location by default. However, because some 32-bit userspace applications are not compatible with inode numbers greater than 2^{32}, XFS will allocate all inodes in disk locations which result in 32-bit inode numbers. This can lead to decreased performance on very large filesystems (that is, larger than 2 terabytes), because inodes are skewed to the beginning of the block device, while data is skewed towards the end.

To address this, use the **inode64** mount option. This option configures XFS to allocate inodes and data across the entire file system, which can improve performance:

```
# mount -o inode64 /dev/device /mount/point
```

Write Barriers

By default, XFS uses write barriers to ensure file system integrity even when power is lost to a device with write caches enabled. For devices without write caches, or with battery-backed write caches, disable the barriers by using the **nobarrier** option:

```
# mount -o nobarrier /dev/device /mount/point
```

For more information about write barriers, refer to Chapter 22, *Write Barriers*.

8.3. XFS Quota Management

The XFS quota subsystem manages limits on disk space (blocks) and file (inode) usage. XFS quotas control or report on usage of these items on a user, group, or directory or project level. Also, note that while user, group, and directory or project quotas are enabled independently, group and project quotas are mutually exclusive.

When managing on a per-directory or per-project basis, XFS manages the disk usage of directory hierarchies associated with a specific project. In doing so, XFS recognizes cross-organizational "group" boundaries between projects. This provides a level of control that is broader than what is available when managing quotas for users or groups.

XFS quotas are enabled at mount time, with specific mount options. Each mount option can also be specified as **noenforce**; this will allow usage reporting without enforcing any limits. Valid quota mount options are:

- **uquota**/**uqnoenforce** - User quotas
- **gquota**/**gqnoenforce** - Group quotas
- **pquota**/**pqnoenforce** - Project quota

Once quotas are enabled, the **xfs_quota** tool can be used to set limits and report on disk usage. By default, **xfs_quota** is run interactively, and in *basic mode*. Basic mode sub-commands simply report usage, and are available to all users. Basic **xfs_quota** sub-commands include:

quota ***username/userID***

Show usage and limits for the given ***username*** or numeric ***userID***

df

Shows free and used counts for blocks and inodes.

In contrast, **xfs_quota** also has an *expert mode*. The sub-commands of this mode allow actual configuration of limits, and are available only to users with elevated privileges. To use expert mode sub-commands interactively, run **xfs_quota -x**. Expert mode sub-commands include:

report ***/path***

Reports quota information for a specific file system.

limit

Modify quota limits.

For a complete list of sub-commands for either basic or expert mode, use the sub-command **help**.

All sub-commands can also be run directly from a command line using the **-c** option, with **-x** for expert sub-commands.

Example 8.2. Display a sample quota report

For example, to display a sample quota report for **/home** (on **/dev/blockdevice**), use the command **xfs_quota -cx 'report -h' /home**. This will display output similar to the following:

```
User quota on /home (/dev/blockdevice)
                        Blocks
User ID      Used   Soft   Hard Warn/Grace
---------- ---------------------------------
root            0      0      0  00 [------]
testuser   103.4G      0      0  00 [------]
...
```

To set a soft and hard inode count limit of 500 and 700 respectively for user **john** (whose home directory is **/home/john**), use the following command:

```
# xfs_quota -x -c 'limit isoft=500 ihard=700 /home/john'
```

By default, the **limit** sub-command recognizes targets as users. When configuring the limits for a group, use the **-g** option (as in the previous example). Similarly, use **-p** for projects.

Soft and hard block limits can also be configured using **bsoft** or **bhard** instead of **isoft** or **ihard**.

Example 8.3. Set a soft and hard block limit

For example, to set a soft and hard block limit of 1000m and 1200m, respectively, to group **accounting** on the **/target/path** file system, use the following command:

```
# xfs_quota -x -c 'limit -g bsoft=1000m bhard=1200m accounting'
/target/path
```

Important

While real-time blocks (**rtbhard**/**rtbsoft**) are described in **man xfs_quota** as valid units when setting quotas, the real-time sub-volume is not enabled in this release. As such, the **rtbhard** and **rtbsoft** options are not applicable.

Setting Project Limits

Before configuring limits for project-controlled directories, add them first to **/etc/projects**. Project names can be added to **/etc/projectid** to map project IDs to project names. Once a project is added to **/etc/projects**, initialize its project directory using the following command:

```
# xfs_quota -c 'project -s projectname'
```

Quotas for projects with initialized directories can then be configured, with:

```
# xfs_quota -x -c 'limit -p bsoft=1000m bhard=1200m projectname'
```

Generic quota configuration tools (**quota**, **repquota**, and **edquota** for example) may also be used to manipulate XFS quotas. However, these tools cannot be used with XFS project quotas.

For more information about setting XFS quotas, refer to **man xfs_quota**.

8.4. Increasing the Size of an XFS File System

An XFS file system may be grown while mounted using the **xfs_growfs** command:

```
# xfs_growfs /mount/point -D size
```

The **-D *size*** option grows the file system to the specified ***size*** (expressed in file system blocks). Without the **-D *size*** option, **xfs_growfs** will grow the file system to the maximum size supported by the device.

Before growing an XFS file system with **-D *size***, ensure that the underlying block device is of an appropriate size to hold the file system later. Use the appropriate resizing methods for the affected block device.

Note

While XFS file systems can be grown while mounted, their size cannot be reduced at all.

For more information about growing a file system, refer to **man xfs_growfs**.

8.5. Repairing an XFS File System

To repair an XFS file system, use **xfs_repair**:

```
# xfs_repair /dev/device
```

The **xfs_repair** utility is highly scalable and is designed to repair even very large file systems with many inodes efficiently. Unlike other Linux file systems, **xfs_repair** does not run at boot time, even when an XFS file system was not cleanly unmounted. In the event of an unclean unmount, **xfs_repair** simply replays the log at mount time, ensuring a consistent file system.

Warning

The **xfs_repair** utility cannot repair an XFS file system with a dirty log. To clear the log, mount and unmount the XFS file system. If the log is corrupt and cannot be replayed, use the **-L** option ("force log zeroing") to clear the log, that is, **xfs_repair -L /dev/device**. Be aware that this may result in further corruption or data loss.

For more information about repairing an XFS file system, refer to **man xfs_repair**.

8.6. Suspending an XFS File System

To suspend or resume write activity to a file system, use **xfs_freeze**. Suspending write activity allows hardware-based device snapshots to be used to capture the file system in a consistent state.

Note

The **xfs_freeze** utility is provided by the **xfsprogs** package, which is only available on x86_64.

To suspend (that is, freeze) an XFS file system, use:

```
# xfs_freeze -f /mount/point
```

To unfreeze an XFS file system, use:

```
# xfs_freeze -u /mount/point
```

When taking an LVM snapshot, it is not necessary to use **xfs_freeze** to suspend the file system first. Rather, the LVM management tools will automatically suspend the XFS file system before taking the snapshot.

Note

The **xfs_freeze** utility can also be used to freeze or unfreeze an ext3, ext4, GFS2, XFS, and BTRFS, file system. The syntax for doing so is the same.

For more information about freezing and unfreezing an XFS file system, refer to **man xfs_freeze**.

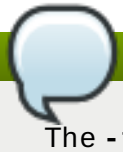
8.7. Backup and Restoration of XFS File Systems

XFS file system backup and restoration involves two utilities: **xfsdump** and **xfsrestore**.

To backup or dump an XFS file system, use the **xfsdump** utility. Red Hat Enterprise Linux 6 supports backups to tape drives or regular file images, and also allows multiple dumps to be written to the same tape. The **xfsdump** utility also allows a dump to span multiple tapes, although only one dump can be written to a regular file. In addition, **xfsdump** supports incremental backups, and can exclude files from a backup using size, subtree, or inode flags to filter them.

In order to support incremental backups, **xfsdump** uses *dump levels* to determine a base dump to which a specific dump is relative. The **-l** option specifies a dump level (*0-9*). To perform a full backup, perform a *level 0* dump on the file system (that is, ***/path/to/filesystem***), as in:

```
# xfsdump -l 0 -f /dev/device /path/to/filesystem
```



Note

The **-f** option specifies a destination for a backup. For example, the **/dev/st0** destination is normally used for tape drives. An **xfsdump** destination can be a tape drive, regular file, or remote tape device.

In contrast, an incremental backup will only dump files that changed since the last *level 0* dump. A *level 1* dump is the first incremental dump after a full dump; the next incremental dump would be *level 2*, and so on, to a maximum of *level 9*. So, to perform a *level 1* dump to a tape drive:

```
# xfsdump -l 1 -f /dev/st0 /path/to/filesystem
```

Conversely, the **xfsrestore** utility restores file systems from dumps produced by **xfsdump**. The **xfsrestore** utility has two modes: a default *simple* mode, and a *cumulative* mode. Specific dumps are identified by *session ID* or *session label*. As such, restoring a dump requires its corresponding session ID or label. To display the session ID and labels of all dumps (both full and incremental), use the **-I** option:

```
# xfsrestore -I
```

This will provide output similar to the following:

Example 8.4. Session ID and labels of all dumps

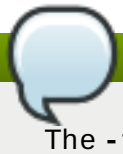
```
file system 0:
 fs id:  45e9af35-efd2-4244-87bc-4762e476cbab
 session 0:
  mount point: bear-05:/mnt/test
  device:  bear-05:/dev/sdb2
  time:  Fri Feb 26 16:55:21 2010
  session label: "my_dump_session_label"
  session id: b74a3586-e52e-4a4a-8775-c3334fa8ea2c
  level:  0
  resumed: NO
  subtree: NO
  streams: 1
  stream 0:
   pathname: /mnt/test2/backup
```

```
    start:  ino 0 offset 0
    end:  ino 1 offset 0
    interrupted: NO
    media files: 1
    media file 0:
     mfile index: 0
     mfile type: data
     mfile size: 21016
     mfile start: ino 0 offset 0
     mfile end: ino 1 offset 0
     media label: "my_dump_media_label"
     media id: 4a518062-2a8f-4f17-81fd-bb1eb2e3cb4f
xfsrestore: Restore Status: SUCCESS
```

Simple Mode for `xfsrestore`

The *simple* mode allows users to restore an entire file system from a *level 0* dump. After identifying a *level 0* dump's session ID (that is, ***session-ID***), restore it fully to ***/path/to/destination*** using:

```
# xfsrestore -f /dev/st0 -S session-ID /path/to/destination
```



Note

The **-f** option specifies the location of the dump, while the **-S** or **-L** option specifies which specific dump to restore. The **-S** option is used to specify a session ID, while the **-L** option is used for session labels. The **-I** option displays both session labels and IDs for each dump.

Cumulative Mode for `xfsrestore`

The *cumulative* mode of **xfsrestore** allows file system restoration from a specific incremental backup, for example, *level 1* to *level 9*. To restore a file system from an incremental backup, simply add the **-r** option:

```
# xfsrestore -f /dev/st0 -S session-ID -r /path/to/destination
```

Interactive Operation

The **xfsrestore** utility also allows specific files from a dump to be extracted, added, or deleted. To use **xfsrestore** interactively, use the **-i** option, as in:

```
xfsrestore -f /dev/st0 -i
```

The interactive dialogue will begin after **xfsrestore** finishes reading the specified device. Available commands in this dialogue include **cd**, **ls**, **add**, **delete**, and **extract**; for a complete list of commands, use **help**.

For more information about dumping and restoring XFS file systems, refer to **man xfsdump** and **man xfsrestore**.

8.8. Other XFS File System Utilities

Red Hat Enterprise Linux 6 also features other utilities for managing XFS file systems:

xfs_fsr

Used to defragment mounted XFS file systems. When invoked with no arguments, **xfs_fsr** defragments all regular files in all mounted XFS file systems. This utility also allows users to suspend a defragmentation at a specified time and resume from where it left off later.

In addition, **xfs_fsr** also allows the defragmentation of only one file, as in **xfs_fsr *path/to/file***. Red Hat advises against periodically defragmenting an entire file system, as this is normally not warranted.

xfs_bmap

Prints the map of disk blocks used by files in an XFS filesystem. This map lists each extent used by a specified file, as well as regions in the file with no corresponding blocks (that is, holes).

xfs_info

Prints XFS file system information.

xfs_admin

Changes the parameters of an XFS file system. The **xfs_admin** utility can only modify parameters of unmounted devices or file systems.

xfs_copy

Copies the contents of an entire XFS file system to one or more targets in parallel.

The following utilities are also useful in debugging and analyzing XFS file systems:

xfs_metadump

Copies XFS file system metadata to a file. The **xfs_metadump** utility should only be used to copy unmounted, read-only, or frozen/suspended file systems; otherwise, generated dumps could be corrupted or inconsistent.

xfs_mdrestore

Restores an XFS metadump image (generated using **xfs_metadump**) to a file system image.

xfs_db

Debugs an XFS file system.

For more information about these utilities, refer to their respective **man** pages.

Chapter 9. Network File System (NFS)

A *Network File System* (*NFS*) allows remote hosts to mount file systems over a network and interact with those file systems as though they are mounted locally. This enables system administrators to consolidate resources onto centralized servers on the network.

This chapter focuses on fundamental NFS concepts and supplemental information.

9.1. How NFS Works

Currently, there are three versions of NFS. NFS version 2 (NFSv2) is older and widely supported. NFS version 3 (NFSv3) supports safe asynchronous writes and is more robust at error handling than NFSv2; it also supports 64-bit file sizes and offsets, allowing clients to access more than 2Gb of file data.

NFS version 4 (NFSv4) works through firewalls and on the Internet, no longer requires an **rpcbind** service, supports ACLs, and utilizes stateful operations. Red Hat Enterprise Linux 6 supports NFSv2, NFSv3, and NFSv4 clients. When mounting a file system via NFS, Red Hat Enterprise Linux uses NFSv4 by default, if the server supports it.

All versions of NFS can use *Transmission Control Protocol* (*TCP*) running over an IP network, with NFSv4 requiring it. NFSv2 and NFSv3 can use the *User Datagram Protocol* (UDP) running over an IP network to provide a stateless network connection between the client and server.

When using NFSv2 or NFSv3 with UDP, the stateless UDP connection (under normal conditions) has less protocol overhead than TCP. This can translate into better performance on very clean, non-congested networks. However, because UDP is stateless, if the server goes down unexpectedly, UDP clients continue to saturate the network with requests for the server. In addition, when a frame is lost with UDP, the entire RPC request must be retransmitted; with TCP, only the lost frame needs to be resent. For these reasons, TCP is the preferred protocol when connecting to an NFS server.

The mounting and locking protocols have been incorporated into the NFSv4 protocol. The server also listens on the well-known TCP port 2049. As such, NFSv4 does not need to interact with **rpcbind** [3], **lockd**, and **rpc.statd** daemons. The **rpc.mountd** daemon is required on the NFS server to set up the exports.

Note

TCP is the default transport protocol for NFS version 2 and 3 under Red Hat Enterprise Linux. UDP can be used for compatibility purposes as needed, but is not recommended for wide usage. NFSv4 requires TCP.

All the RPC/NFS daemons have a **'-p'** command line option that can set the port, making firewall configuration easier.

After TCP wrappers grant access to the client, the NFS server refers to the **/etc/exports** configuration file to determine whether the client is allowed to access any exported file systems. Once verified, all file and directory operations are available to the user.

Important

In order for NFS to work with a default installation of Red Hat Enterprise Linux with a firewall enabled, configure IPTables with the default TCP port 2049. Without proper IPTables configuration, NFS will not function properly.

The NFS initialization script and **rpc.nfsd** process now allow binding to any specified port during system start up. However, this can be error-prone if the port is unavailable, or if it conflicts with another daemon.

9.1.1. Required Services

Red Hat Enterprise Linux uses a combination of kernel-level support and daemon processes to provide NFS file sharing. All NFS versions rely on *Remote Procedure Calls* (*RPC*) between clients and servers. RPC services under Red Hat Enterprise Linux 6 are controlled by the **rpcbind** service. To share or mount NFS file systems, the following services work together depending on which version of NFS is implemented:

Note

The **portmap** service was used to map RPC program numbers to IP address port number combinations in earlier versions of Red Hat Enterprise Linux. This service is now replaced by **rpcbind** in Red Hat Enterprise Linux 6 to enable IPv6 support. For more information about this change, refer to the following links:

- *TI-RPC / rpcbind support*: http://nfsv4.bullopensource.org/doc/tirpc_rpcbind.php
- *IPv6 support in NFS*: http://nfsv4.bullopensource.org/doc/nfs_ipv6.php

nfs

service nfs start starts the NFS server and the appropriate RPC processes to service requests for shared NFS file systems.

nfslock

service nfslock start activates a mandatory service that starts the appropriate RPC processes allowing NFS clients to lock files on the server.

rpcbind

rpcbind accepts port reservations from local RPC services. These ports are then made available (or advertised) so the corresponding remote RPC services can access them. **rpcbind** responds to requests for RPC services and sets up connections to the requested RPC service. This is not used with NFSv4.

rpc.nfsd

rpc.nfsd allows explicit NFS versions and protocols the server advertises to be defined. It works with the Linux kernel to meet the dynamic demands of NFS clients, such as providing server threads each time an NFS client connects. This process corresponds to the **nfs** service.

The following RPC processes facilitate NFS services:

rpc.mountd

This process is used by an NFS server to process **MOUNT** requests from NFSv2 and NFSv3 clients. It checks that the requested NFS share is currently exported by the NFS server, and that the client is allowed to access it. If the mount request is allowed, the rpc.mountd server replies with a **Success** status and provides the **File-Handle** for this NFS share back to the NFS client.

lockd

lockd is a kernel thread which runs on both clients and servers. It implements the *Network Lock Manager* (NLM) protocol, which allows NFSv2 and NFSv3 clients to lock files on the server. It is started automatically whenever the NFS server is run and whenever an NFS file system is mounted.

rpc.statd

This process implements the *Network Status Monitor* (NSM) RPC protocol, which notifies NFS clients when an NFS server is restarted without being gracefully brought down. **rpc.statd** is started automatically by the **nfslock** service, and does not require user configuration. This is not used with NFSv4.

rpc.rquotad

This process provides user quota information for remote users. **rpc.rquotad** is started automatically by the **nfs** service and does not require user configuration.

rpc.idmapd

rpc.idmapd provides NFSv4 client and server upcalls, which map between on-the-wire NFSv4 names (which are strings in the form of ***user*@*domain***) and local UIDs and GIDs. For **idmapd** to function with NFSv4, the **/etc/idmapd.conf** file must be configured. This service is required for use with NFSv4, although not when all hosts share the same DNS domain name. Refer to the knowledge base article https://access.redhat.com/site/solutions/130783 when using a local domain.

9.2. pNFS

Support for Parallel NFS (pNFS) as part of the NFS v4.1 standard is available as of Red Hat Enterprise Linux 6.4. The pNFS architecture improves the scalability of NFS, with possible improvements to performance. That is, when a server implements pNFS as well, a client is able to access data through multiple servers concurrently. It supports three storage protocols or layouts: files, objects, and blocks.

To enable this functionality, use one of the following mount options on mounts from a pNFS-enabled server:

```
-o minorversion=1
```

or

```
-o v4.1
```

After the server is pNFS-enabled, the **nfs_layout_nfsv41_files** kernel is automatically loaded on the first mount. Use the following command to verify the module was loaded:

```
$ lsmod | grep nfs_layout_nfsv41_files
```

Another way to verify a successful NFSv4.1 mount is with the **mount** command. The mount entry in the output should contain **minorversion=1**.

Important

The protocol allows for three possible pNFS layout types: files, objects, and blocks. However the Red Hat Enterprise Linux 6.4 client only supports the files layout type, so will use pNFS only when the server also supports the files layout type.

For more information on pNFS, refer to: http://www.pnfs.com.

9.3. NFS Client Configuration

The **mount** command mounts NFS shares on the client side. Its format is as follows:

```
# mount -t nfs -o options host:/remote/export /local/directory
```

This command uses the following variables:

options

A comma-delimited list of mount options; refer to Section 9.5, "Common NFS Mount Options" for details on valid NFS mount options.

server

The hostname, IP address, or fully qualified domain name of the server exporting the file system you wish to mount

/remote/export

The file system or directory being exported from the *server*, that is, the directory you wish to mount

/local/directory

The client location where */remote/export* is mounted

The NFS protocol version used in Red Hat Enterprise Linux 6 is identified by the **mount** options **nfsvers** or **vers**. By default, **mount** will use NFSv4 with **mount -t nfs**. If the server does not support NFSv4, the client will automatically step down to a version supported by the server. If the **nfsvers**/**vers** option is used to pass a particular version not supported by the server, the mount will fail. The file system type nfs4 is also available for legacy reasons; this is equivalent to running **mount -t nfs -o nfsvers=4 *host*:*/remote/export* *local/directory***.

Refer to **man mount** for more details.

If an NFS share was mounted manually, the share will not be automatically mounted upon reboot. Red Hat Enterprise Linux offers two methods for mounting remote file systems automatically at boot time: the **/etc/fstab** file and the **autofs** service. Refer to Section 9.3.1, "Mounting NFS File Systems using **/etc/fstab**" and Section 9.4, "**autofs**" for more information.

9.3.1. Mounting NFS File Systems using `/etc/fstab`

An alternate way to mount an NFS share from another machine is to add a line to the **/etc/fstab** file. The line must state the hostname of the NFS server, the directory on the server being exported, and the directory on the local machine where the NFS share is to be mounted. You must be root to modify the **/etc/fstab** file.

Example 9.1. Syntax example

The general syntax for the line in **/etc/fstab** is as follows:

```
server:/usr/local/pub    /pub    nfs    defaults 0 0
```

The mount point **/pub** must exist on the client machine before this command can be executed. After adding this line to **/etc/fstab** on the client system, use the command **mount /pub**, and the mount point **/pub** is mounted from the server.

The **/etc/fstab** file is referenced by the **netfs** service at boot time, so lines referencing NFS shares have the same effect as manually typing the **mount** command during the boot process.

A valid **/etc/fstab** entry to mount an NFS export should contain the following information:

```
server:/remote/export /local/directory nfs options 0 0
```

The variables *server*, */remote/export*, */local/directory*, and *options* are the same ones used when manually mounting an NFS share. Refer to Section 9.3, “NFS Client Configuration” for a definition of each variable.

Note

The mount point */local/directory* must exist on the client before **/etc/fstab** is read. Otherwise, the mount will fail.

For more information about **/etc/fstab**, refer to **man fstab**.

9.4. `autofs`

One drawback to using **/etc/fstab** is that, regardless of how infrequently a user accesses the NFS mounted file system, the system must dedicate resources to keep the mounted file system in place. This is not a problem with one or two mounts, but when the system is maintaining mounts to many systems at one time, overall system performance can be affected. An alternative to **/etc/fstab** is to use the kernel-based **automount** utility. An automounter consists of two components:

- a kernel module that implements a file system, and
- a user-space daemon that performs all of the other functions.

The **automount** utility can mount and unmount NFS file systems automatically (on-demand mounting), therefore saving system resources. It can be used to mount other file systems including AFS, SMBFS, CIFS, and local file systems.

Important

The nfs-utils package is now a part of both the 'NFS file server' and the 'Network File System Client' groups. As such, it is no longer installed by default with the Base group. Ensure that nfs-utils is installed on the system first before attempting to automount an NFS share.

autofs is also part of the 'Network File System Client' group.

autofs uses **/etc/auto.master** (master map) as its default primary configuration file. This can be changed to use another supported network source and name using the **autofs** configuration (in **/etc/sysconfig/autofs**) in conjunction with the Name Service Switch (NSS) mechanism. An instance of the **autofs** version 4 daemon was run for each mount point configured in the master map and so it could be run manually from the command line for any given mount point. This is not possible with **autofs** version 5, because it uses a single daemon to manage all configured mount points; as such, all automounts must be configured in the master map. This is in line with the usual requirements of other industry standard automounters. Mount point, hostname, exported directory, and options can all be specified in a set of files (or other supported network sources) rather than configuring them manually for each host.

9.4.1. Improvements in autofs Version 5 over Version 4

autofs version 5 features the following enhancements over version 4:

Direct map support

Direct maps in **autofs** provide a mechanism to automatically mount file systems at arbitrary points in the file system hierarchy. A direct map is denoted by a mount point of **/-** in the master map. Entries in a direct map contain an absolute path name as a key (instead of the relative path names used in indirect maps).

Lazy mount and unmount support

Multi-mount map entries describe a hierarchy of mount points under a single key. A good example of this is the **-hosts** map, commonly used for automounting all exports from a host under **/net/*host*** as a multi-mount map entry. When using the **-hosts** map, an **ls** of **/net/*host*** will mount *autofs* trigger mounts for each export from *host*. These will then mount and expire them as they are accessed. This can greatly reduce the number of active mounts needed when accessing a server with a large number of exports.

Enhanced LDAP support

The **autofs** configuration file (**/etc/sysconfig/autofs**) provides a mechanism to specify the **autofs** schema that a site implements, thus precluding the need to determine this via trial and error in the application itself. In addition, authenticated binds to the LDAP server are now supported, using most mechanisms supported by the common LDAP server implementations. A new configuration file has been added for this support: **/etc/autofs_ldap_auth.conf**. The default configuration file is self-documenting, and uses an XML format.

Proper use of the Name Service Switch (nsswitch) configuration.

The Name Service Switch configuration file exists to provide a means of determining from where specific configuration data comes. The reason for this configuration is to allow administrators the flexibility of using the back-end database of choice, while maintaining a uniform software interface to access the data. While the version 4 automounter is becoming

increasingly better at handling the NSS configuration, it is still not complete. Autofs version 5, on the other hand, is a complete implementation.

Refer to **man nsswitch.conf** for more information on the supported syntax of this file. Not all NSS databases are valid map sources and the parser will reject ones that are invalid. Valid sources are files, **yp**, **nis**, **nisplus**, **ldap**, and **hesiod**.

Multiple master map entries per autofs mount point

One thing that is frequently used but not yet mentioned is the handling of multiple master map entries for the direct mount point **/-**. The map keys for each entry are merged and behave as one map.

Example 9.2. Multiple master map entries per autofs mount point

An example is seen in the connectathon test maps for the direct mounts below:

```
/- /tmp/auto_dcthon
/- /tmp/auto_test3_direct
/- /tmp/auto_test4_direct
```

9.4.2. autofs Configuration

The primary configuration file for the automounter is **/etc/auto.master**, also referred to as the master map which may be changed as described in the Section 9.4.1, “Improvements in autofs Version 5 over Version 4”. The master map lists **autofs**-controlled mount points on the system, and their corresponding configuration files or network sources known as automount maps. The format of the master map is as follows:

```
mount-point map-name options
```

The variables used in this format are:

mount-point

The **autofs** mount point, **/home**, for example.

map-name

The name of a map source which contains a list of mount points, and the file system location from which those mount points should be mounted. The syntax for a map entry is described below.

options

If supplied, these will apply to all entries in the given map provided they don't themselves have options specified. This behavior is different from **autofs** version 4 where options were cumulative. This has been changed to implement mixed environment compatibility.

Example 9.3. /etc/auto.master file

> The following is a sample line from **/etc/auto.master** file (displayed with **cat /etc/auto.master**):
>
> ```
> /home /etc/auto.misc
> ```
>
> The general format of maps is similar to the master map, however the "options" appear between the mount point and the location instead of at the end of the entry as in the master map:
>
> ```
> mount-point   [options]   location
> ```

The variables used in this format are:

mount-point

This refers to the **autofs** mount point. This can be a single directory name for an indirect mount or the full path of the mount point for direct mounts. Each direct and indirect map entry key (***mount-point*** above) may be followed by a space separated list of offset directories (sub directory names each beginning with a "/") making them what is known as a multi-mount entry.

options

Whenever supplied, these are the mount options for the map entries that do not specify their own options.

location

This refers to the file system location such as a local file system path (preceded with the Sun map format escape character ":" for map names beginning with "/"), an NFS file system or other valid file system location.

The following is a sample of contents from a map file (for example, **/etc/auto.misc**):

```
payroll -fstype=nfs personnel:/exports/payroll
sales -fstype=ext3 :/dev/hda4
```

The first column in a map file indicates the **autofs** mount point (**sales** and **payroll** from the server called **personnel**). The second column indicates the options for the **autofs** mount while the third column indicates the source of the mount. Following the above configuration, the autofs mount points will be **/home/payroll** and **/home/sales**. The **-fstype=** option is often omitted and is generally not needed for correct operation.

The automounter will create the directories if they do not exist. If the directories exist before the automounter was started, the automounter will not remove them when it exits. You can start or restart the automount daemon by issuing either of the following two commands:

- **service autofs start** (if the automount daemon has stopped)
- **service autofs restart**

Using the above configuration, if a process requires access to an **autofs** unmounted directory such as **/home/payroll/2006/July.sxc**, the automount daemon automatically mounts the directory. If a timeout is specified, the directory will automatically be unmounted if the directory is not accessed for the timeout period.

You can view the status of the automount daemon by issuing the following command:

```
#  service autofs status
```

9.4.3. Overriding or Augmenting Site Configuration Files

It can be useful to override site defaults for a specific mount point on a client system. For example, consider the following conditions:

- Automounter maps are stored in NIS and the **/etc/nsswitch.conf** file has the following directive:

  ```
  automount:    files nis
  ```

- The **auto.master** file contains the following

  ```
  +auto.master
  ```

- The NIS **auto.master** map file contains the following:

  ```
  /home auto.home
  ```

- The NIS **auto.home** map contains the following:

  ```
  beth        fileserver.example.com:/export/home/beth
  joe        fileserver.example.com:/export/home/joe
  *       fileserver.example.com:/export/home/&
  ```

- The file map **/etc/auto.home** does not exist.

Given these conditions, let's assume that the client system needs to override the NIS map **auto.home** and mount home directories from a different server. In this case, the client will need to use the following **/etc/auto.master** map:

```
/home /etc/auto.home
+auto.master
```

The **/etc/auto.home** map contains the entry:

```
*    labserver.example.com:/export/home/&
```

Because the automounter only processes the first occurrence of a mount point, **/home** will contain the contents of **/etc/auto.home** instead of the NIS **auto.home** map.

Alternatively, to augment the site-wide **auto.home** map with just a few entries, create an **/etc/auto.home** file map, and in it put the new entries. At the end, include the NIS **auto.home** map. Then the **/etc/auto.home** file map will look similar to:

```
mydir someserver:/export/mydir
+auto.home
```

Given the NIS **auto.home** map listed above, **ls /home** would now output:

```
beth joe mydir
```

This last example works as expected because **autofs** does not include the contents of a file map of the same name as the one it is reading. As such, **autofs** moves on to the next map source in the **nsswitch** configuration.

9.4.4. Using LDAP to Store Automounter Maps

LDAP client libraries must be installed on all systems configured to retrieve automounter maps from LDAP. On Red Hat Enterprise Linux, the **openldap** package should be installed automatically as a dependency of the **automounter**. To configure LDAP access, modify **/etc/openldap/ldap.conf**. Ensure that BASE, URI, and schema are set appropriately for your site.

The most recently established schema for storing automount maps in LDAP is described by **rfc2307bis**. To use this schema it is necessary to set it in the **autofs** configuration (**/etc/sysconfig/autofs**) by removing the comment characters from the schema definition. For example:

Example 9.4. Setting autofs configuration

```
DEFAULT_MAP_OBJECT_CLASS="automountMap"
DEFAULT_ENTRY_OBJECT_CLASS="automount"
DEFAULT_MAP_ATTRIBUTE="automountMapName"
DEFAULT_ENTRY_ATTRIBUTE="automountKey"
DEFAULT_VALUE_ATTRIBUTE="automountInformation"
```

Ensure that these are the only schema entries not commented in the configuration. The **automountKey** replaces the **cn** attribute in the **rfc2307bis** schema. An **LDIF** of a sample configuration is described below:

Example 9.5. LDF configuration

```
# extended LDIF
#
# LDAPv3
# base <> with scope subtree
# filter: (&(objectclass=automountMap)(automountMapName=auto.master))
# requesting: ALL
#

# auto.master, example.com
dn: automountMapName=auto.master,dc=example,dc=com
objectClass: top
objectClass: automountMap
automountMapName: auto.master

# extended LDIF
#
# LDAPv3
# base <automountMapName=auto.master,dc=example,dc=com> with scope
subtree
# filter: (objectclass=automount)
# requesting: ALL
#
```

```
# /home, auto.master, example.com
dn: automountMapName=auto.master,dc=example,dc=com
objectClass: automount
cn: /home

automountKey: /home
automountInformation: auto.home

# extended LDIF
#
# LDAPv3
# base <> with scope subtree
# filter: (&(objectclass=automountMap)(automountMapName=auto.home))
# requesting: ALL
#

# auto.home, example.com
dn: automountMapName=auto.home,dc=example,dc=com
objectClass: automountMap
automountMapName: auto.home

# extended LDIF
#
# LDAPv3
# base <automountMapName=auto.home,dc=example,dc=com> with scope
subtree
# filter: (objectclass=automount)
# requesting: ALL
#

# foo, auto.home, example.com
dn: automountKey=foo,automountMapName=auto.home,dc=example,dc=com
objectClass: automount
automountKey: foo
automountInformation: filer.example.com:/export/foo

# /, auto.home, example.com
dn: automountKey=/,automountMapName=auto.home,dc=example,dc=com
objectClass: automount
automountKey: /
automountInformation: filer.example.com:/export/&
```

9.5. Common NFS Mount Options

Beyond mounting a file system with NFS on a remote host, it is also possible to specify other options at mount time to make the mounted share easier to use. These options can be used with manual **mount** commands, **/etc/fstab** settings, and **autofs**.

The following are options commonly used for NFS mounts:

intr

Allows NFS requests to be interrupted if the server goes down or cannot be reached.

lookupcache=*mode*

Specifies how the kernel should manage its cache of directory entries for a given mount point. Valid arguments for *mode* are **all**, **none**, or **pos**/**positive**.

nfsvers=*version*

Specifies which version of the NFS protocol to use, where *version* is 2, 3, or 4. This is useful for hosts that run multiple NFS servers. If no version is specified, NFS uses the highest version supported by the kernel and **mount** command.

The option **vers** is identical to **nfsvers**, and is included in this release for compatibility reasons.

noacl

Turns off all ACL processing. This may be needed when interfacing with older versions of Red Hat Enterprise Linux, Red Hat Linux, or Solaris, since the most recent ACL technology is not compatible with older systems.

nolock

Disables file locking. This setting is occasionally required when connecting to older NFS servers.

noexec

Prevents execution of binaries on mounted file systems. This is useful if the system is mounting a non-Linux file system containing incompatible binaries.

nosuid

Disables **set-user-identifier** or **set-group-identifier** bits. This prevents remote users from gaining higher privileges by running a **setuid** program.

port=*num*

port=num — Specifies the numeric value of the NFS server port. If ***num*** is **0** (the default), then **mount** queries the remote host's **rpcbind** service for the port number to use. If the remote host's NFS daemon is not registered with its **rpcbind** service, the standard NFS port number of TCP 2049 is used instead.

rsize=*num* and wsize=*num*

These settings speed up NFS communication for reads (**rsize**) and writes (**wsize**) by setting a larger data block size (*num*, in bytes), to be transferred at one time. Be careful when changing these values; some older Linux kernels and network cards do not work well with larger block sizes.

Note

If an rsize value is not specified, or if the specified value is larger than the maximum that either client or server can support, then the client and server negotiate the largest resize value they can both support.

sec=*mode*

Specifies the type of security to utilize when authenticating an NFS connection. Its default

setting is **sec=sys**, which uses local UNIX UIDs and GIDs by using **AUTH_SYS** to authenticate NFS operations.

sec=krb5 uses Kerberos V5 instead of local UNIX UIDs and GIDs to authenticate users.

sec=krb5i uses Kerberos V5 for user authentication and performs integrity checking of NFS operations using secure checksums to prevent data tampering.

sec=krb5p uses Kerberos V5 for user authentication, integrity checking, and encrypts NFS traffic to prevent traffic sniffing. This is the most secure setting, but it also involves the most performance overhead.

tcp

Instructs the NFS mount to use the TCP protocol.

udp

Instructs the NFS mount to use the UDP protocol.

For a complete list of options and more detailed information on each one, refer to **man mount** and **man nfs**.

9.6. Starting and Stopping NFS

To run an NFS server, the **rpcbind**[3] service must be running. To verify that **rpcbind** is active, use the following command:

```
# service rpcbind status
```

If the **rpcbind** service is running, then the **nfs** service can be started. To start an NFS server, use the following command:

```
# service nfs start
```

nfslock must also be started for both the NFS client and server to function properly. To start NFS locking, use the following command:

```
# service nfslock start
```

If NFS is set to start at boot, ensure that **nfslock** also starts by running **chkconfig --list nfslock**. If **nfslock** is not set to **on**, this implies that you will need to manually run the **service nfslock start** each time the computer starts. To set **nfslock** to automatically start on boot, use **chkconfig nfslock on**.

nfslock is only needed for NFSv2 and NFSv3.

To stop the server, use:

```
# service nfs stop
```

The **restart** option is a shorthand way of stopping and then starting NFS. This is the most efficient way to make configuration changes take effect after editing the configuration file for NFS. To restart the server type:

```
# service nfs restart
```

The **condrestart** (*conditional restart*) option only starts **nfs** if it is currently running. This option is useful for scripts, because it does not start the daemon if it is not running. To conditionally restart the server type:

```
# service nfs condrestart
```

To reload the NFS server configuration file without restarting the service type:

```
# service nfs reload
```

9.7. NFS Server Configuration

There are two ways to configure an NFS server:

- Manually editing the NFS configuration file, that is, **/etc/exports**, and
- through the command line, that is, by using the command **exportfs**

9.7.1. The /etc/exports Configuration File

The **/etc/exports** file controls which file systems are exported to remote hosts and specifies options. It follows the following syntax rules:

- Blank lines are ignored.
- To add a comment, start a line with the hash mark (#).
- You can wrap long lines with a backslash (\).
- Each exported file system should be on its own individual line.
- Any lists of authorized hosts placed after an exported file system must be separated by space characters.
- Options for each of the hosts must be placed in parentheses directly after the host identifier, without any spaces separating the host and the first parenthesis.

Each entry for an exported file system has the following structure:

```
export host(options)
```

The aforementioned structure uses the following variables:

export

The directory being exported

host

The host or network to which the export is being shared

options

The options to be used for *host*

It is possible to specify multiple hosts, along with specific options for each host. To do so, list them on the same line as a space-delimited list, with each hostname followed by its respective options (in parentheses), as in:

```
export host1(options1) host2(options2) host3(options3)
```

For information on different methods for specifying hostnames, refer to Section 9.7.4, “Hostname Formats”.

In its simplest form, the **/etc/exports** file only specifies the exported directory and the hosts permitted to access it, as in the following example:

Example 9.6. The /etc/exports file

```
/exported/directory bob.example.com
```

Here, **bob.example.com** can mount **/exported/directory/** from the NFS server. Because no options are specified in this example, NFS will use *default* settings.

The default settings are:

ro

The exported file system is read-only. Remote hosts cannot change the data shared on the file system. To allow hosts to make changes to the file system (that is, read/write), specify the **rw** option.

sync

The NFS server will not reply to requests before changes made by previous requests are written to disk. To enable asynchronous writes instead, specify the option **async**.

wdelay

The NFS server will delay writing to the disk if it suspects another write request is imminent. This can improve performance as it reduces the number of times the disk must be accesses by separate write commands, thereby reducing write overhead. To disable this, specify the **no_wdelay**. **no_wdelay** is only available if the default **sync** option is also specified.

root_squash

This prevents root users connected *remotely* (as opposed to locally) from having root privileges; instead, the NFS server will assign them the user ID **nfsnobody**. This effectively "squashes" the power of the remote root user to the lowest local user, preventing possible unauthorized writes on the remote server. To disable root squashing, specify **no_root_squash**.

To squash every remote user (including root), use **all_squash**. To specify the user and group IDs that the NFS server should assign to remote users from a particular host, use the **anonuid** and **anongid** options, respectively, as in:

```
export host(anonuid=uid,anongid=gid)
```

Here, *uid* and *gid* are user ID number and group ID number, respectively. The **anonuid** and **anongid** options allow you to create a special user and group account for remote NFS users to share.

By default, *access control lists* (*ACLs*) are supported by NFS under Red Hat Enterprise Linux. To disable this feature, specify the **no_acl** option when exporting the file system.

Each default for every exported file system must be explicitly overridden. For example, if the **rw** option is not specified, then the exported file system is shared as read-only. The following is a sample line from **/etc/exports** which overrides two default options:

```
/another/exported/directory 192.168.0.3(rw,async)
```

In this example **192.168.0.3** can mount **/another/exported/directory/** read/write and all writes to disk are asynchronous. For more information on exporting options, refer to **man exportfs**.

Other options are available where no default value is specified. These include the ability to disable sub-tree checking, allow access from insecure ports, and allow insecure file locks (necessary for certain early NFS client implementations). Refer to **man exports** for details on these less-used options.

Important

The format of the **/etc/exports** file is very precise, particularly in regards to use of the space character. Remember to always separate exported file systems from hosts and hosts from one another with a space character. However, there should be no other space characters in the file except on comment lines.

For example, the following two lines do not mean the same thing:

```
/home bob.example.com(rw)
/home bob.example.com (rw)
```

The first line allows only users from **bob.example.com** read/write access to the **/home** directory. The second line allows users from **bob.example.com** to mount the directory as read-only (the default), while the rest of the world can mount it read/write.

9.7.2. The exportfs Command

Every file system being exported to remote users with NFS, as well as the access level for those file systems, are listed in the **/etc/exports** file. When the **nfs** service starts, the **/usr/sbin/exportfs** command launches and reads this file, passes control to **rpc.mountd** (if NFSv2 or NFSv3) for the actual mounting process, then to **rpc.nfsd** where the file systems are then available to remote users.

When issued manually, the **/usr/sbin/exportfs** command allows the root user to selectively export or unexport directories without restarting the NFS service. When given the proper options, the **/usr/sbin/exportfs** command writes the exported file systems to **/var/lib/nfs/etab**. Since **rpc.mountd** refers to the **etab** file when deciding access privileges to a file system, changes to the list of exported file systems take effect immediately.

The following is a list of commonly-used options available for **/usr/sbin/exportfs**:

-r

Causes all directories listed in **/etc/exports** to be exported by constructing a new export list in **/etc/lib/nfs/etab**. This option effectively refreshes the export list with any changes made to **/etc/exports**.

-a

Causes all directories to be exported or unexported, depending on what other options are passed to **/usr/sbin/exportfs**. If no other options are specified, **/usr/sbin/exportfs** exports all file systems specified in **/etc/exports**.

-o *file-systems*

Specifies directories to be exported that are not listed in **/etc/exports**. Replace *file-systems* with additional file systems to be exported. These file systems must be formatted in the same way they are specified in **/etc/exports**. This option is often used to test an exported file system before adding it permanently to the list of file systems to be exported. Refer to Section 9.7.1, “The **/etc/exports** Configuration File” for more information on **/etc/exports** syntax.

-i

Ignores **/etc/exports**; only options given from the command line are used to define exported file systems.

-u

Unexports all shared directories. The command **/usr/sbin/exportfs -ua** suspends NFS file sharing while keeping all NFS daemons up. To re-enable NFS sharing, use **exportfs -r**.

-v

Verbose operation, where the file systems being exported or unexported are displayed in greater detail when the **exportfs** command is executed.

If no options are passed to the **exportfs** command, it displays a list of currently exported file systems. For more information about the **exportfs** command, refer to **man exportfs**.

9.7.2.1. Using exportfs with NFSv4

In Red Hat Enterprise Linux 6, no extra steps are required to configure NFSv4 exports as any filesystems mentioned are automatically available to NFSv2, NFSv3, and NFSv4 clients using the same path. This was not the case in previous versions.

To prevent clients from using NFSv4, turn it off by sellecting **RPCNFSDARGS= -N 4** in **/etc/sysconfig/nfs**.

9.7.3. Running NFS Behind a Firewall

NFS requires **rpcbind**, which dynamically assigns ports for RPC services and can cause problems for configuring firewall rules. To allow clients to access NFS shares behind a firewall, edit the **/etc/sysconfig/nfs** configuration file to control which ports the required RPC services run on.

The **/etc/sysconfig/nfs** may not exist by default on all systems. If it does not exist, create it and add the following variables, replacing *port* with an unused port number (alternatively, if the file exists, un-comment and change the default entries as required):

MOUNTD_PORT=*port*

Controls which TCP and UDP port **mountd** (**rpc.mountd**) uses.

STATD_PORT=*port*

Controls which TCP and UDP port status (**rpc.statd**) uses.

LOCKD_TCPPORT=*port*

Controls which TCP port **nlockmgr** (**lockd**) uses.

LOCKD_UDPPORT=*port*

Controls which UDP port **nlockmgr** (**lockd**) uses.

If NFS fails to start, check **/var/log/messages**. Normally, NFS will fail to start if you specify a port number that is already in use. After editing **/etc/sysconfig/nfs**, restart the NFS service using **service nfs restart**. Run the **rpcinfo -p** command to confirm the changes.

To configure a firewall to allow NFS, perform the following steps:

Procedure 9.1. Configure a firewall to allow NFS

1. Allow TCP and UDP port 2049 for NFS.
2. Allow TCP and UDP port 111 (**rpcbind**/**sunrpc**).
3. Allow the TCP and UDP port specified with **MOUNTD_PORT="*port*"**
4. Allow the TCP and UDP port specified with **STATD_PORT="*port*"**
5. Allow the TCP port specified with **LOCKD_TCPPORT="*port*"**
6. Allow the UDP port specified with **LOCKD_UDPPORT="*port*"**

Note

To allow NFSv4.0 callbacks to pass through firewalls set **/proc/sys/fs/nfs/nfs_callback_tcpport** and allow the server to connect to that port on the client.

This process is not needed for NFSv4.1 or higher, and the other ports for **mountd**, **statd**, and **lockd** are not required in a pure NFSv4 environment.

9.7.3.1. Discovering NFS exports

There are two ways to discover which file systems an NFS server exports.

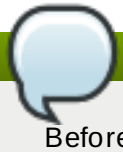
First, on any server that supports NFSv2 or NFSv3, use the **showmount** command:

```
$ showmount -e myserver
Export list for mysever
/exports/foo
/exports/bar
```

Second, on any server that supports NFSv4, mount **/** and look around.

```
# mount myserver:/ /mnt/
#cd /mnt/
exports
# ls exports
foo
bar
```

On servers that support both NFSv4 and either NFSv2 or NFSv3, both methods will work and give the same results.



Note

Before Red Hat Enterprise Linux 6 on older NFS servers, depending on how they are configured, it is possible to export filesystems to NFSv4 clients at different paths. Because these servers do not enable NFSv4 by default this should not normally be a problem.

9.7.4. Hostname Formats

The host(s) can be in the following forms:

Single machine

A fully-qualified domain name (that can be resolved by the server), hostname (that can be resolved by the server), or an IP address.

Series of machines specified with wildcards

Use the ***** or **?** character to specify a string match. Wildcards are not to be used with IP addresses; however, they may accidentally work if reverse DNS lookups fail. When specifying wildcards in fully qualified domain names, dots (**.**) are not included in the wildcard. For example, ***.example.com** includes **one.example.com** but does not **include one.two.example.com**.

IP networks

Use *a.b.c.d/z*, where *a.b.c.d* is the network and *z* is the number of bits in the netmask (for example 192.168.0.0/24). Another acceptable format is *a.b.c.d/netmask*, where *a.b.c.d* is the network and *netmask* is the netmask (for example, 192.168.100.8/255.255.255.0).

Netgroups

Use the format *@group-name*, where *group-name* is the NIS netgroup name.

9.7.5. NFS over RDMA

To enable the RDMA transport in the linux kernel NFS server, use the following procedure:

Procedure 9.2. Enable RDMA from server

1. Ensure the RDMA rpm is installed and the RDMA service is enabled with the following command:

```
# yum install rdma; chkconfig --level 2345 rdma on
```

2. Ensure the package that provides the nfs-rdma service is installed and the service is enabled with the following command:

```
# yum install rdma; chkconfig --level 345 nfs-rdma on
```

3. Ensure that the RDMA port is set to the preferred port (default for Red Hat Enterprise Linux 6 is 2050). To do so, edit the **/etc/rdma/rdma.conf** file to set NFSoRDMA_LOAD=yes and NFSoRDMA_PORT to the desired port.

4. Set up the exported filesystem as normal for NFS mounts.

On the client side, use the following procedure:

Procedure 9.3. Enable RDMA from client

1. Ensure the RDMA rpm is installed and the RDMA service is enabled with the following command:

```
# yum install rdma; chkconfig --level 2345 rdma on
```

2. Mount the NFS exported partition using the RDMA option on the mount call. The port option can optionally be added to the call.

```
# mount -t nfs -o rdma,port=port_number
```

9.8. Securing NFS

NFS is well-suited for sharing entire file systems with a large number of known hosts in a transparent manner. However, with ease-of-use comes a variety of potential security problems. Consider the following sections when exporting NFS file systems on a server or mounting them on a client. Doing so minimizes NFS security risks and better protects data on the server.

9.8.1. NFS Security with AUTH_SYS and export controls

Traditionally, NFS has given two options in order to control access to exported files.

First, the server restricts which hosts are allowed to mount which filesystems either by IP address or by host name.

Second, the server enforces file system permissions for users on NFS clients in the same way it does local users. Traditionally it does this using **AUTH_SYS** (also called **AUTH_UNIX**) which relies on the client to state the UID and GID's of the user. Be aware that this means a malicious or misconfigured client can easily get this wrong and allow a user access to files that it should not.

To limit the potential risks, administrators often allow read-only access or squash user permissions to a common user and group ID. Unfortunately, these solutions prevent the NFS share from being used in the way it was originally intended.

Additionally, if an attacker gains control of the DNS server used by the system exporting the NFS file system, the system associated with a particular hostname or fully qualified domain name can be pointed to an unauthorized machine. At this point, the unauthorized machine *is* the system permitted to mount the NFS share, since no username or password information is exchanged to provide additional security for the NFS mount.

Wildcards should be used sparingly when exporting directories through NFS, as it is possible for the scope of the wildcard to encompass more systems than intended.

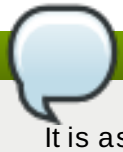
It is also possible to restrict access to the **rpcbind**[3] service with TCP wrappers. Creating rules with **iptables** can also limit access to ports used by **rpcbind**, **rpc.mountd**, and **rpc.nfsd**.

For more information on securing NFS and **rpcbind**, refer to **man iptables**.

9.8.2. NFS security with AUTH_GSS

The release of NFSv4 brought a revolution to NFS security by mandating the implementation of RPCSEC_GSS and the Kerberos version 5 GSS-API mechanism. However, RPCSEC_GSS and the Kerberos mechanism are also available for all versions of NFS.

With the RPCSEC_GSS Kerberos mechanism, the server no longer depends on the client to correctly represent which user is accessing the file, as is the case with AUTH_SYS. Instead, it uses cryptography to authenticate users to the server, preventing a malicious client from impersonating a user without having that user's kerberos credentials.



Note

It is assumed that a Kerberos ticket-granting server (KDC) is installed and configured correctly, prior to configuring an NFSv4 server. Kerberos is a network authentication system which allows clients and servers to authenticate to each other through use of symmetric encryption and a trusted third party, the KDC. For more information on Kerberos see Red Hat's *Identity Management Guide*.

To set up RPCSEC_GSS, use the following procedure:

Procedure 9.4. Set up RPCSEC_GSS

1. Create **nfs/client.*mydomain*@*MYREALM*** and **nfs/server.*mydomain*@*MYREALM*** principals.
2. Add the corresponding keys to keytabs for the client and server.
3. On the server side, add **sec=krb5,krb5i,krb5p** to the export. To continue allowing AUTH_SYS, add **sec=sys,krb5,krb5i,krb5p** instead.
4. On the client side, add **sec=krb5** (or **sec=krb5i**, or **sec=krb5p** depending on the set up) to the mount options.

For more information, such as the difference between **krb5**, **krb5i**, and **krb5p**, refer to the **exports** and **nfs** man pages or to Section 9.5, “Common NFS Mount Options”.

For more information on the **RPCSEC_GSS** framework, including how **rpc.svcgssd** and **rpc.gssd** inter-operate, refer to http://www.citi.umich.edu/projects/nfsv4/gssd/.

9.8.2.1. NFS security with NFSv4

NFSv4 includes ACL support based on the Microsoft Windows NT model, not the POSIX model, because of the former's features and wide deployment.

Another important security feature of NFSv4 is the removal of the use of the **MOUNT** protocol for mounting file systems. This protocol presented possible security holes because of the way that it processed file handles.

9.8.3. File Permissions

Once the NFS file system is mounted read/write by a remote host, the only protection each shared file has is its permissions. If two users that share the same user ID value mount the same NFS file system, they can modify each others' files. Additionally, anyone logged in as root on the client system can use the **su -** command to access any files with the NFS share.

By default, access control lists (ACLs) are supported by NFS under Red Hat Enterprise Linux. Red Hat recommends that this feature is kept enabled.

By default, NFS uses *root squashing* when exporting a file system. This sets the user ID of anyone accessing the NFS share as the root user on their local machine to **nobody**. Root squashing is controlled by the default option **root_squash**; for more information about this option, refer to Section 9.7.1, “The **/etc/exports** Configuration File”. If possible, never disable root squashing.

When exporting an NFS share as read-only, consider using the **all_squash** option. This option makes every user accessing the exported file system take the user ID of the **nfsnobody** user.

9.9. NFS and rpcbind

Note

The following section only applies to NFSv2 or NFSv3 implementations that require the **rpcbind** service for backward compatibility.

The **rpcbind**[3] utility maps RPC services to the ports on which they listen. RPC processes notify **rpcbind** when they start, registering the ports they are listening on and the RPC program numbers they expect to serve. The client system then contacts **rpcbind** on the server with a particular RPC program number. The **rpcbind** service redirects the client to the proper port number so it can communicate with the requested service.

Because RPC-based services rely on **rpcbind** to make all connections with incoming client requests, **rpcbind** must be available before any of these services start.

The **rpcbind** service uses TCP wrappers for access control, and access control rules for **rpcbind** affect *all* RPC-based services. Alternatively, it is possible to specify access control rules for each of the NFS RPC daemons. The **man** pages for **rpc.mountd** and **rpc.statd** contain information regarding the precise syntax for these rules.

9.9.1. Troubleshooting NFS and rpcbind

Because **rpcbind**[3] provides coordination between RPC services and the port numbers used to communicate with them, it is useful to view the status of current RPC services using **rpcbind** when troubleshooting. The **rpcinfo** command shows each RPC-based service with port numbers, an RPC program number, a version number, and an IP protocol type (TCP or UDP).

To make sure the proper NFS RPC-based services are enabled for **rpcbind**, issue the following command:

```
# rpcinfo -p
```

Example 9.7. `rpcinfo -p` command output

The following is sample output from this command:

```
program vers proto   port service
      100021    1   udp  32774  nlockmgr
      100021    3   udp  32774  nlockmgr
      100021    4   udp  32774  nlockmgr
      100021    1   tcp  34437  nlockmgr
      100021    3   tcp  34437  nlockmgr
      100021    4   tcp  34437  nlockmgr
      100011    1   udp    819  rquotad
      100011    2   udp    819  rquotad
      100011    1   tcp    822  rquotad
      100011    2   tcp    822  rquotad
      100003    2   udp   2049  nfs
      100003    3   udp   2049  nfs
      100003    2   tcp   2049  nfs
      100003    3   tcp   2049  nfs
      100005    1   udp    836  mountd
      100005    1   tcp    839  mountd
      100005    2   udp    836  mountd
      100005    2   tcp    839  mountd
      100005    3   udp    836  mountd
      100005    3   tcp    839  mountd
```

If one of the NFS services does not start up correctly, **rpcbind** will be unable to map RPC requests from clients for that service to the correct port. In many cases, if NFS is not present in **rpcinfo** output, restarting NFS causes the service to correctly register with **rpcbind** and begin working.

For more information and a list of options on **rpcinfo**, refer to its **man** page.

9.10. References

Administering an NFS server can be a challenge. Many options, including quite a few not mentioned in this chapter, are available for exporting or mounting NFS shares. Consult the following sources for more information.

Installed Documentation

- **man mount** — Contains a comprehensive look at mount options for both NFS server and client configurations.
- **man fstab** — Gives details for the format of the **/etc/fstab** file used to mount file systems at boot-time.
- **man nfs** — Provides details on NFS-specific file system export and mount options.
- **man exports** — Shows common options used in the **/etc/exports** file when exporting NFS file systems.

Useful Websites

- http://linux-nfs.org — The current site for developers where project status updates can be viewed.
- http://nfs.sourceforge.net/ — The old home for developers which still contains a lot of useful information.
- http://www.citi.umich.edu/projects/nfsv4/linux/ — An NFSv4 for Linux 2.6 kernel resource.
- http://www.vanemery.com/Linux/NFSv4/NFSv4-no-rpcsec.html — Describes the details of NFSv4 with Fedora Core 2, which includes the 2.6 kernel.
- http://citeseer.ist.psu.edu/viewdoc/summary?doi=10.1.1.111.4086 — An excellent whitepaper on the features and enhancements of the NFS Version 4 protocol.

Related Books

- *Managing NFS and NIS* by Hal Stern, Mike Eisler, and Ricardo Labiaga; O'Reilly & Associates — Makes an excellent reference guide for the many different NFS export and mount options available as of 2001.
- *NFS Illustrated* by Brent Callaghan; Addison-Wesley Publishing Company — Provides comparisons of NFS to other network file systems and shows, in detail, how NFS communication occurs.

[3] The **rpcbind** service replaces **portmap**, which was used in previous versions of Red Hat Enterprise Linux to map RPC program numbers to IP address port number combinations. For more information, refer to Section 9.1.1, “Required Services”.

Chapter 10. FS-Cache

FS-Cache is a persistent local cache that can be used by file systems to take data retrieved from over the network and cache it on local disk. This helps minimize network traffic for users accessing data from a file system mounted over the network (for example, NFS).

The following diagram is a high-level illustration of how FS-Cache works:

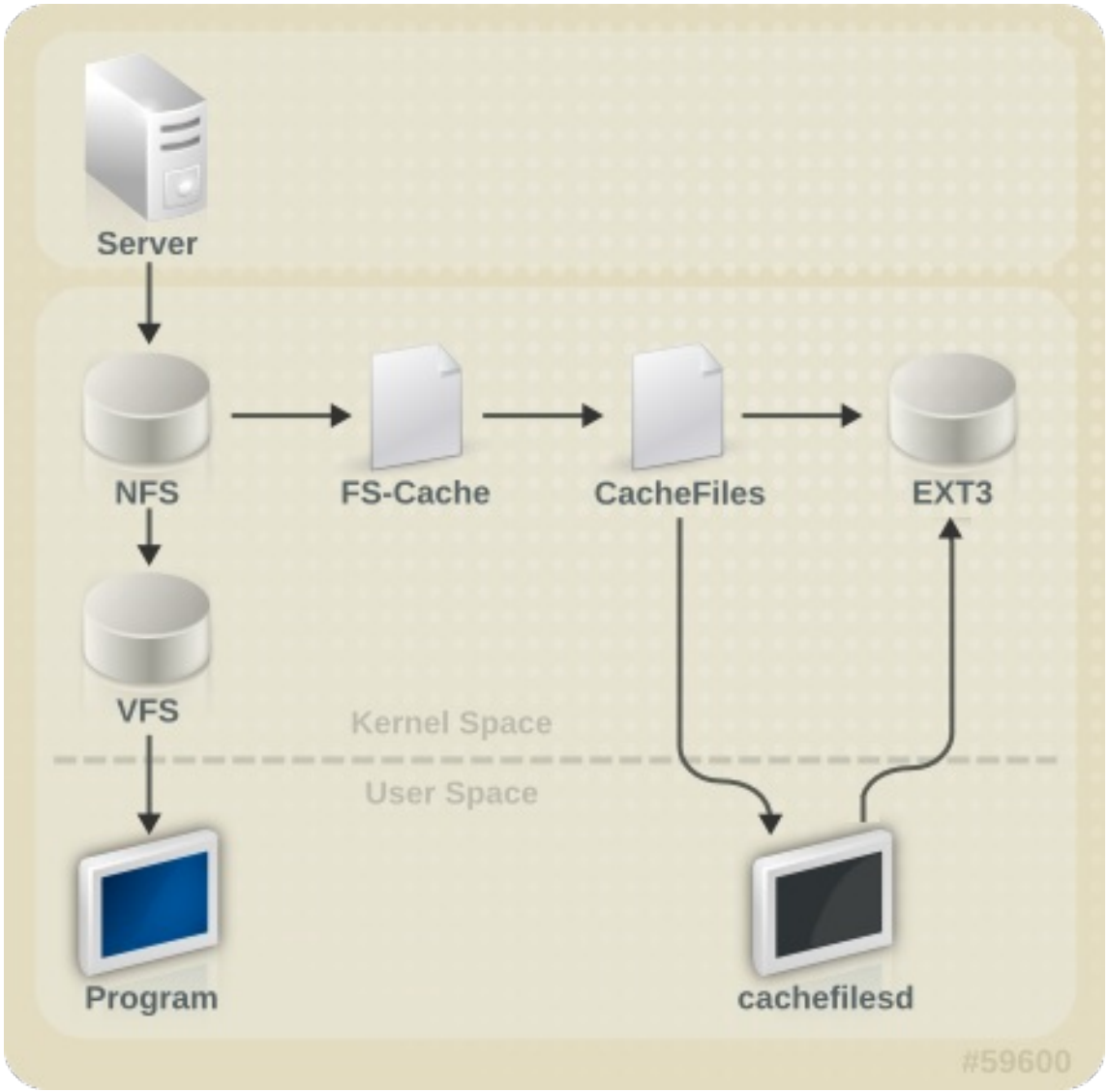


Figure 10.1. FS-Cache Overview

FS-Cache is designed to be as transparent as possible to the users and administrators of a system. Unlike **cachefs** on Solaris, FS-Cache allows a file system on a server to interact directly with a client's local cache without creating an overmounted file system. With NFS, a mount option instructs the client to mount the NFS share with FS-cache enabled.

FS-Cache does not alter the basic operation of a file system that works over the network - it merely provides that file system with a persistent place in which it can cache data. For instance, a client can still mount an NFS share whether or not FS-Cache is enabled. In addition, cached NFS can handle files that won't fit into the cache (whether individually or collectively) as files can be partially cached and do not have to be read completely up front. FS-Cache also hides all I/O errors that occur in the cache from the client file system driver.

To provide caching services, FS-Cache needs a *cache back-end*. A cache back-end is a storage driver configured to provide caching services (i.e. **cachefiles**). In this case, FS-Cache requires a mounted block-based file system that supports **bmap** and extended attributes (e.g. ext3) as its cache back-end.

FS-Cache cannot arbitrarily cache any file system, whether through the network or otherwise: the shared file system's driver must be altered to allow interaction with FS-Cache, data storage/retrieval, and metadata set up and validation. FS-Cache needs *indexing keys* and *coherency data* from the cached file system to support persistence: indexing keys to match file system objects to cache objects, and coherency data to determine whether the cache objects are still valid.

Note: cachefilesd

In Red Hat Enterprise Linux 6.2 including all previous versions, **cachefilesd** is not installed by default and will need to be installed manually.

10.1. Performance Guarantee

FS-Cache does *not* guarantee increased performance, however it ensures consistent performance by avoiding network congestion. Using a cache back-end incurs a performance penalty: for example, cached NFS shares add disk accesses to cross-network lookups. While FS-Cache tries to be as asynchronous as possible, there are synchronous paths (e.g. reads) where this isn't possible.

For example, using FS-Cache to cache an NFS share between two computers over an otherwise unladen GigE network will not demonstrate any performance improvements on file access. Rather, NFS requests would be satisfied faster from server memory rather than from local disk.

The use of FS-Cache, therefore, is a *compromise* between various factors. If FS-Cache is being used to cache NFS traffic, for instance, it may slow the client down a little, but massively reduce the network and server loading by satisfying read requests locally without consuming network bandwidth.

10.2. Setting Up a Cache

Currently, Red Hat Enterprise Linux 6 only provides the **cachefiles** caching back-end. The **cachefilesd** daemon initiates and manages **cachefiles**. The **/etc/cachefilesd.conf** file controls how **cachefiles** provides caching services. To configure a cache back-end of this type, the **cachefilesd** package must be installed.

The first setting to configure in a cache back-end is which directory to use as a cache. To configure this, use the following parameter:

```
$ dir /path/to/cache
```

Typically, the cache back-end directory is set in **/etc/cachefilesd.conf** as **/var/cache/fscache**, as in:

```
$ dir /var/cache/fscache
```

FS-Cache will store the cache in the file system that hosts */path/to/cache*. On a laptop, it is advisable to use the root file system (**/**) as the host file system, but for a desktop machine it would be more prudent to mount a disk partition specifically for the cache.

File systems that support functionalities required by FS-Cache cache back-end include the Red Hat Enterprise Linux 6 implementations of the following file systems:

- ext3 (with extended attributes enabled)
- ext4
- BTRFS
- XFS

The host file system must support user-defined extended attributes; FS-Cache uses these attributes to store coherency maintenance information. To enable user-defined extended attributes for ext3 file systems (i.e. ***device***), use:

```
# tune2fs -o user_xattr /dev/device
```

Alternatively, extended attributes for a file system can be enabled at mount time, as in:

```
# mount /dev/device /path/to/cache -o user_xattr
```

The cache back-end works by maintaining a certain amount of free space on the partition hosting the cache. It grows and shrinks the cache in response to other elements of the system using up free space, making it safe to use on the root file system (for example, on a laptop). FS-Cache sets defaults on this behavior, which can be configured via *cache cull limits*. For more information about configuring cache cull limits, refer to Section 10.4, “Setting Cache Cull Limits”.

Once the configuration file is in place, start up the **cachefilesd** daemon:

```
# service cachefilesd start
```

To configure **cachefilesd** to start at boot time, execute the following command as root:

```
# chkconfig cachefilesd on
```

10.3. Using the Cache With NFS

NFS will not use the cache unless explicitly instructed. To configure an NFS mount to use FS-Cache, include the **-o fsc** option to the **mount** command:

```
# mount nfs-share:/ /mount/point -o fsc
```

All access to files under ***/mount/point*** will go through the cache, unless the file is opened for direct I/O or writing (refer to Section 10.3.2, “Cache Limitations With NFS” for more information). NFS indexes cache contents using NFS file handle, *not* the file name; this means that hard-linked files share the cache correctly.

Caching is supported in version 2, 3, and 4 of NFS. However, each version uses different branches for caching.

10.3.1. Cache Sharing

There are several potential issues to do with NFS cache sharing. Because the cache is persistent, blocks of data in the cache are indexed on a sequence of four keys:

- Level 1: Server details
- Level 2: Some mount options; security type; FSID; uniquifier
- Level 3: File Handle
- Level 4: Page number in file

To avoid coherency management problems between superblocks, all NFS superblocks that wish to cache data have unique Level 2 keys. Normally, two NFS mounts with same source volume and options will share a superblock, and thus share the caching, even if they mount different directories within that volume.

Example 10.1. Cache sharing

Take the following two **mount** commands:

```
mount home0:/disk0/fred /home/fred -o fsc

mount home0:/disk0/jim /home/jim -o fsc
```

Here, **/home/fred** and **/home/jim** will likely share the superblock as they have the same options, especially if they come from the same volume/partition on the NFS server (**home0**). Now, consider the next two subsequent mount commands:

```
mount home0:/disk0/fred /home/fred -o fsc,rsize=230

mount home0:/disk0/jim /home/jim -o fsc,rsize=231
```

In this case, **/home/fred** and **/home/jim** will not share the superblock as they have different network access parameters, which are part of the Level 2 key. The same goes for the following mount sequence:

```
mount home0:/disk0/fred /home/fred1 -o fsc,rsize=230

mount home0:/disk0/fred /home/fred2 -o fsc,rsize=231
```

Here, the contents of the two subtrees (**/home/fred1** and **/home/fred2**) will be cached *twice*.

Another way to avoid superblock sharing is to suppress it explicitly with the **nosharecache** parameter. Using the same example:

```
mount home0:/disk0/fred /home/fred -o nosharecache,fsc

mount home0:/disk0/jim /home/jim -o nosharecache,fsc
```

However, in this case only one of the superblocks will be permitted to use cache since there is nothing to distinguish the Level 2 keys of **home0:/disk0/fred** and **home0:/disk0/jim**. To address this, add a *unique identifier* on at least one of the mounts, i.e. **fsc=*unique-identifier***. For example:

```
mount home0:/disk0/fred /home/fred -o nosharecache,fsc

mount home0:/disk0/jim /home/jim -o nosharecache,fsc=jim
```

Here, the unique identifier **jim** will be added to the Level 2 key used in the cache for **/home/jim**.

10.3.2. Cache Limitations With NFS

Opening a file from a shared file system for direct I/O will automatically bypass the cache. This is because this type of access must be direct to the server.

Opening a file from a shared file system for writing will not work on NFS version 2 and 3. The protocols of these versions do not provide sufficient coherency management information for the client to detect a concurrent write to the same file from another client.

As such, opening a file from a shared file system for either direct I/O or writing will flush the cached copy of the file. FS-Cache will not cache the file again until it is no longer opened for direct I/O or writing.

Furthermore, this release of FS-Cache only caches regular NFS files. FS-Cache will *not* cache directories, symlinks, device files, FIFOs and sockets.

10.4. Setting Cache Cull Limits

The **cachefilesd** daemon works by caching remote data from shared file systems to free space on the disk. This could potentially consume all available free space, which could be bad if the disk also housed the root partition. To control this, **cachefilesd** tries to maintain a certain amount of free space by discarding old objects (i.e. accessed less recently) from the cache. This behavior is known as *cache culling*.

Cache culling is done on the basis of the percentage of blocks and the percentage of files available in the underlying file system. There are six limits controlled by settings in **/etc/cachefilesd.conf**:

brun *N*% (percentage of blocks) , frun *N*% (percentage of files)

If the amount of free space and the number of available files in the cache rises above both these limits, then culling is turned off.

bcull *N*% (percentage of blocks), fcull *N*% (percentage of files)

If the amount of available space or the number of files in the cache falls below either of these limits, then culling is started.

bstop *N*% (percentage of blocks), fstop *N*% (percentage of files)

If the amount of available space or the number of available files in the cache falls below either of these limits, then no further allocation of disk space or files is permitted until culling has raised things above these limits again.

The default value of **N** for each setting is as follows:

- **brun**/**frun** - 10%
- **bcull**/**fcull** - 7%
- **bstop**/**fstop** - 3%

When configuring these settings, the following must hold true:

0 <= **bstop** < **bcull** < **brun** < 100

0 <= **fstop** < **fcull** < **frun** < 100

These are the percentages of available space and available files and do not appear as 100 minus the percentage displayed by the **df** program.

Important

Culling depends on both b*xxx* and f*xxx* pairs simultaneously; they can not be treated separately.

10.5. Statistical Information

FS-Cache also keeps track of general statistical information. To view this information, use:

```
cat /proc/fs/fscache/stats
```

FS-Cache statistics includes information on decision points and object counters. For more details on the statistics provided by FS-Cache, refer to the following kernel document:

/usr/share/doc/kernel-doc-*version*/Documentation/filesystems/caching/fscache.txt

10.6. References

For more information on **cachefilesd** and how to configure it, refer to **man cachefilesd** and **man cachefilesd.conf**. The following kernel documents also provide additional information:

- **/usr/share/doc/cachefilesd-*version-number*/README**
- **/usr/share/man/man5/cachefilesd.conf.5.gz**
- **/usr/share/man/man8/cachefilesd.8.gz**

For general information about FS-Cache, including details on its design constraints, available statistics, and capabilities, refer to the following kernel document:

/usr/share/doc/kernel-doc-*version*/Documentation/filesystems/caching/fscache.txt

Part II. Storage Administration

The Storage Administration section starts with storage considerations for Red Hat Enterprise Linux 6. Instructions regarding partitions, logical volume management, and swap partitions follow this. Disk Quotas, RAID systems are next, followed by the functions of mount command, volume_key, and acls. SSD tuning, write barriers, I/O limits and diskless systems follow this. The large chapter of Online Storage is next, and finally device mapper multipathing and virtual storage to finish.

Use the following Table of Contents to explore these Storage Administration tasks.

Chapter 11. Storage Considerations During Installation

Many storage device and file system settings can only be configured at install time. Other settings, such as file system type, can only be modified up to a certain point without requiring a reformat. As such, it is prudent that you plan your storage configuration accordingly before installing Red Hat Enterprise Linux 6.

This chapter discusses several considerations when planning a storage configuration for your system. For actual installation instructions (including storage configuration during installation), refer to the *Installation Guide* provided by Red Hat.

11.1. Updates to Storage Configuration During Installation

Installation configuration for the following settings/devices has been updated for Red Hat Enterprise Linux 6:

Fibre-Channel over Ethernet (FCoE)

Anaconda can now configure FCoE storage devices during installation.

Storage Device Filtering Interface

Anaconda now has improved control over which storage devices are used during installation. You can now control which devices are available/visible to the installer, in addition to which devices are actually used for system storage. There are two paths through device filtering:

Basic Path

For systems that only use locally attached disks and firmware RAID arrays as storage devices

Advanced Path

For systems that use SAN (e.g. multipath, iSCSI, FCoE) devices

Auto-partitioning and /home

Auto-partitioning now creates a separate logical volume for the **/home** file system when 50GB or more is available for allocation of LVM physical volumes. The root file system (**/**) will be limited to a maximum of 50GB when creating a separate **/home** logical volume, but the **/home** logical volume will grow to occupy all remaining space in the volume group.

11.2. Overview of Supported File Systems

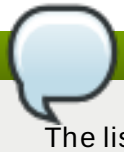
This section shows basic technical information on each file system supported by Red Hat Enterprise Linux 6.

Table 11.1. Technical Specifications of Supported File Systems

File System	Max Supported Size	Max File Offset	Max Subdirectories (per directory)	Max Depth of Symbolic Links	ACL Support	Details
Ext2	8TB	2TB	32,000	8	Yes	N/A

File System	Max Supported Size	Max File Offset	Max Subdirectories (per directory)	Max Depth of Symbolic Links	ACL Support	Details
Ext3	16TB	2TB	32,000	8	Yes	Chapter 5, *The Ext3 File System*
Ext4	16TB	16TB [a]	Unlimited [b]	8	Yes	Chapter 6, *The Ext4 File System*
XFS	100TB	100TB [c]	Unlimited	8	Yes	Chapter 8, *The XFS File System*

[a] This maximum file size is based on a 64-bit machine. On a 32-bit machine, the maximum files size is 8TB.
[b] When the link count exceeds 65,000, it is reset to 1 and no longer increases.
[c] This maximum file size is only on 64-bit machines. Red Hat Enterprise Linux does not support XFS on 32-bit machines.



Note: Maximum file and file system sizes

The listed maximum file and file system sizes are what Red Hat has tested and supports. This does not take into account the theoretical maximum limits.

Both the maximum supported size and maximum file offset columns assume 4k blocks.

11.3. Special Considerations

This section enumerates several issues and factors to consider for specific storage configurations.

Separate Partitions for /home, /opt, /usr/local

If it is likely that you will upgrade your system in the future, place **/home**, **/opt**, and **/usr/local** on a separate device. This will allow you to reformat the devices/file systems containing the operating system while preserving your user and application data.

DASD and zFCP Devices on IBM System Z

On the IBM System Z platform, DASD and zFCP devices are configured via the *Channel Command Word* (CCW) mechanism. CCW paths must be explicitly added to the system and then brought online. For DASD devices, this is simply means listing the device numbers (or device number ranges) as the **DASD=** parameter at the boot command line or in a CMS configuration file.

For zFCP devices, you must list the device number, *logical unit number* (LUN), and *world wide port name* (WWPN). Once the zFCP device is initialized, it is mapped to a CCW path. The **FCP_x=** lines on the boot command line (or in a CMS configuration file) allow you to specify this information for the installer.

Encrypting Block Devices Using LUKS

Formatting a block device for encryption using LUKS/**dm-crypt** will destroy any existing formatting on that device. As such, you should decide which devices to encrypt (if any) before the new system's storage configuration is activated as part of the installation process.

Stale BIOS RAID Metadata

Moving a disk from a system configured for firmware RAID *without* removing the RAID metadata from the disk can prevent **Anaconda** from correctly detecting the disk.

Warning

Removing/deleting RAID metadata from disk could potentially destroy any stored data. Red Hat recommends that you back up your data before proceeding.

To delete RAID metadata from the disk, use the following command:

```
dmraid -r -E /device/
```

For more information about managing RAID devices, refer to **man dmraid** and Chapter 17, *Redundant Array of Independent Disks (RAID)*.

iSCSI Detection and Configuration

For plug and play detection of iSCSI drives, configure them in the firmware of an iBFT boot-capable *network interface card* (NIC). CHAP authentication of iSCSI targets is supported during installation. However, iSNS discovery is not supported during installation.

FCoE Detection and Configuration

For plug and play detection of *fibre-channel over ethernet* (FCoE) drives, configure them in the firmware of an EDD boot-capable NIC.

DASD

Direct-access storage devices (DASD) cannot be added/configured during installation. Such devices are specified in the CMS configuration file.

Block Devices with DIF/DIX Enabled

DIF/DIX is a hardware checksum feature provided by certain SCSI host bus adapters and block devices. When DIF/DIX is enabled, errors will occur if the block device is used as a general-purpose block device. Buffered I/O or **mmap(2)**-based I/O will not work reliably, as there are no interlocks in the buffered write path to prevent buffered data from being overwritten after the DIF/DIX checksum has been calculated.

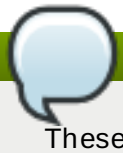
This will cause the I/O to later fail with a checksum error. This problem is common to all block device (or file system-based) buffered I/O or **mmap(2)** I/O, so it is not possible to work around these errors caused by overwrites.

As such, block devices with DIF/DIX enabled should only be used with applications that use **O_DIRECT**. Such applications should use the raw block device. Alternatively, it is also safe to use the XFS file system on a DIF/DIX enabled block device, as long as only **O_DIRECT** I/O is issued through the file system. XFS is the only file system that does not fall back to buffered I/O when doing certain allocation operations.

The responsibility for ensuring that the I/O data does not change after the DIF/DIX checksum has been computed always lies with the application, so only applications designed for use with **O_DIRECT** I/O and DIF/DIX hardware should use DIF/DIX.

Chapter 12. File System Check

Filesystems may be checked for consistency, and optionally repaired, with filesystem-specific userspace tools. These tools are often referred to as **fsck** tools, where **fsck** is a shortened version of *file system check*.



Note

These filesystem checkers only guarantee metadata consistency across the filesystem; they have no awareness of the actual data contained within the filesystem and are not data recovery tools.

Filesystem inconsistencies can occur for various reasons, including but not limited to hardware errors, storage administration errors, and software bugs.

Before modern metadata-journaling filesystems became common, a filesystem check was required any time a system crashed or lost power. This was because a filesystem update could have been interrupted, leading to an inconsistent state. As a result, a filesystem check is traditionally run on each filesystem listed in **/etc/fstab** at boot-time. For journaling filesystems, this is usually a very short operation, because the filesystem's metadata journaling ensures consistency even after a crash.

However, there are times when a filesystem inconsistency or corruption may occur, even for journaling filesystems. When this happens, the filesystem checker must be used to repair the filesystem. The following will provide best practices and other useful information when performing this procedure.

Important

Red Hat does not recommend this unles the machine does not boot, the file system is extremely large, or the file system is on remote storage. It is possible to disable file system check at boot by setting the sixth field in **/etc/fstab** to 0.

12.1. Best Practices for fsck

Generally, running the filesystem check and repair tool can be expected to automatically repair at least some of the inconsistencies it finds. In some cases, severely damaged inodes or directories may be discarded if they cannot be repaired. Significant changes to the filesystem may occur. To ensure that unexpected or undesirable changes are not permanently made, perform the following precautionary steps:

Dry run

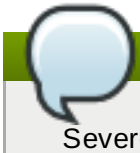
Most filesystem checkers have a mode of operation which checks but does not repair the filesystem. In this mode, the checker will print any errors that it finds and actions that it would have taken, without actually modifying the filesystem.

Note

Later phases of consistency checking may print extra errors as it discovers inconsistencies which would have been fixed in early phases if it were running in repair mode.

Operate first on a filesystem image

Most filesystems support the creation of a *metadata image*, a sparse copy of the filesystem which contains only metadata. Because filesystem checkers operate only on metadata, such an image can be used to perform a dry run of an actual filesystem repair, to evaluate what changes would actually be made. If the changes are acceptable, the repair can then be performed on the filesystem itself.



Note

Severely damaged filesystems may cause problems with metadata image creation.

Save a filesystem image for support investigations

A pre-repair filesystem metadata image can often be useful for support investigations if there is a possibility that the corruption was due to a software bug. Patterns of corruption present in the pre-repair image may aid in root-cause analysis.

Operate only on unmounted filesystems

A filesystem repair must be run only on unmounted filesystems. The tool must have sole access to the filesystem or further damage may result. Most filesystem tools enforce this requirement in repair mode, although some only support check-only mode on a mounted filesystem. If check-only mode is run on a mounted filesystem, it may find spurious errors that would not be found when run on an unmounted filesystem.

Disk errors

Filesystem check tools cannot repair hardware problems. A filesystem must be fully readable and writable if repair is to operate successfully. If a filesystem was corrupted due to a hardware error, the filesystem must first be moved to a good disk, for example with the **dd(8)** utility.

12.2. Filesystem-Specific Information for fsck

12.2.1. ext2, ext3, and ext4

All of these filesytems use the **e2fsck** binary to perform filesystem checks and repairs. The filenames **fsck.ext2**, **fsck.ext3**, and **fsck.ext4** are hardlinks to this same binary. These binaries are run automatically at boot time and their behavior differs based on the filesystem being checked and the state of the filesystem.

A full filesystem check and repair is invoked for ext2, which is not a metadata journaling filesystem, and for ext4 filesystems without a journal.

For ext3 and ext4 filesystems with metadata journaling, the journal is replayed in userspace and the binary exited. This is the default action as journal replay ensures a consistent filesystem after a

crash.

If these filesystems encounter metadata inconsistencies while mounted, they will record this fact in the filesystem superblock. If **e2fsck** finds that a filesystem is marked with such an error **e2fsck** will perform a full check after replaying the journal (if present).

e2fsck may ask for user input during the run if the **-p** option is not specified. The **-p** option tells **e2fsck** to automatically do all repairs that may be done safely. If user intervention is required, **e2fsck** will indicate the unfixed problem in its output and reflect this status in the exit code.

Commonly used **e2fsck** run-time options include:

-n

No-modify mode. Check-only operation.

-b superblock

Specify block number of an alternate superblock if the primary one is damaged.

-f

Force full check even if the superblock has no recorded errors.

-j journal-dev

Specify the external journal device, if any.

-p

Automatically repair or "preen" the filesystem with no user input.

-y

Assume an answer of "yes" to all questions.

All options for **e2fsck** are specified in the **e2fsck(8)** manual page.

The following five basic phases are performed by **e2fsck** while running:

1. Inode, block, and size checks.
2. Directory structure checks.
3. Directory connectivity checks.
4. Reference count checks.
5. Group summary info checks.

The **e2image(8)** utility can be used to create a metadata image prior to repair for diagnostic or testing purposes. The **-r** option should be used for testing purposes in order to create a sparse file of the same size as the filesystem itself. **e2fsck** can then operate directly on the resulting file. The **-Q** option should be specified if the image is to be archived or provided for diagnostic. This creates a more compact file format suitable for transfer.

12.2.2. XFS

No repair is performed automatically at boot time. To initiate a filesystem check or repair, the **xfs_repair** tool is used.

Note

Although an **fsck.xfs** binary is present in the *xfsprogs* package, this is present only to satisfy initscripts that look for an **fsck.*filesystem*** binary at boot time. **fsck.xfs** immediately exits with an exit code of 0.

Another thing to be aware of is that older *xfsprogs* packages contain an **xfs_check** tool. This tool is very slow and does not scale well for large filesystems. As such, it has been depreciated in favor of **xfs_repair -n**.

A clean log on a filesystem is required for **xfs_repair** to operate. If the filesystem was not cleanly unmounted, it should be mounted and unmounted prior to using **xfs_repair**. If the log is corrupt and cannot be replayed, the **-L** option may be used to zero the log.

Important

The **-L** option must only be used if the log cannot be replayed. The option discards all metadata updates in the log and will result in further inconsistencies.

It is possible to run **xfs_repair** in a dry run, check-only mode by using the **-n** option. No changes will be made to the filesystem when this option is specified.

xfs_repair takes very few options. Commonly used options include:

-n

No modify mode. Check-only operation.

-L

Zero metadata log. Use only if log cannot be replayed with mount.

-m maxmem

Limit memory used during run to maxmem MB. 0 can be specified to obtain a rough estimate of the minimum memory required.

-l logdev

Specify the external log device, if present.

All options for **xfs_repair** are specified in the **xfs_repair(8)** manual page.

The following eight basic phases are performed by **xfs_repair** while running:

1. Inode and inode blockmap (addressing) checks.
2. Inode allocation map checks.
3. Inode size checks.
4. Directory checks.
5. Pathname checks.

6. Link count checks.
7. Freemap checks.
8. Superblock checks.

These phases, as well as messages printed during operation, are documented in depth in the **xfs_repair(8)** manual page.

xfs_repair is not interactive. All operations are performed automatically with no input from the user.

If it is desired to create a metadata image prior to repair for diagnostic or testing purposes, the **xfs_metadump(8)** and **xfs_mdrestore(8)** utilities may be used.

12.2.3. Btrfs

The **btrfsck** tool is used to check and repair btrfs filesystems. This tool is still in early development and may not detect or repair all types of filesystem corruption.

By default, **btrfsck** does not make changes to the filesystem; that is, it runs check-only mode by default. If repairs are desired the **--repair** option must be specified.

The following three basic phases are performed by **btrfsck** while running:

1. Extent checks.
2. Filesystem root checks.
3. Root reference count checks.

The **btrfs-image(8)** utility can be used to create a metadata image prior to repair for diagnostic or testing purposes.

Chapter 13. Partitions

The utility **parted** allows users to:

- View the existing partition table
- Change the size of existing partitions
- Add partitions from free space or additional hard drives

By default, the **parted** package is included when installing Red Hat Enterprise Linux. To start **parted**, log in as root and type the command **parted** ***/dev/sda*** at a shell prompt (where ***/dev/sda*** is the device name for the drive you want to configure).

If you want to remove or resize a partition, the device on which that partition resides must not be in use. Creating a new partition on a device which is in use—while possible—is not recommended.

For a device to not be in use, none of the partitions on the device can be mounted, and any swap space on the device must not be enabled.

As well, the partition table should not be modified while it is in use because the kernel may not properly recognize the changes. If the partition table does not match the actual state of the mounted partitions, information could be written to the wrong partition, resulting in lost and overwritten data.

The easiest way to achieve this it to boot your system in rescue mode. When prompted to mount the file system, select **Skip**.

Alternately, if the drive does not contain any partitions in use (system processes that use or lock the file system from being unmounted), you can unmount them with the **umount** command and turn off all the swap space on the hard drive with the **swapoff** command.

Table 13.1, "**parted** commands" contains a list of commonly used **parted** commands. The sections that follow explain some of these commands and arguments in more detail.

Table 13.1. parted commands

Command	Description
check ***minor-num***	Perform a simple check of the file system
cp ***from to***	Copy file system from one partition to another; *from* and *to* are the minor numbers of the partitions
help	Display list of available commands
mklabel ***label***	Create a disk label for the partition table
mkfs ***minor-num file-system-type***	Create a file system of type *file-system-type*
mkpart ***part-type fs-type start-mb end-mb***	Make a partition without creating a new file system
mkpartfs ***part-type fs-type start-mb end-mb***	Make a partition and create the specified file system
move ***minor-num start-mb end-mb***	Move the partition
name ***minor-num name***	Name the partition for Mac and PC98 disklabels only
print	Display the partition table
quit	Quit **parted**
rescue *start-mb end-mb*	Rescue a lost partition from *start-mb* to *end-mb*
resize ***minor-num start-mb end-mb***	Resize the partition from *start-mb* to *end-mb*

Command	Description
rm *minor-num*	Remove the partition
select *device*	Select a different device to configure
set *minor-num flag state*	Set the flag on a partition; *state* is either on or off
toggle [*NUMBER* [*FLAG*]	Toggle the state of *FLAG* on partition *NUMBER*
unit *UNIT*	Set the default unit to *UNIT*

13.1. Viewing the Partition Table

After starting **parted**, use the command **print** to view the partition table. A table similar to the following appears:

Example 13.1. Partition table

```
Model: ATA ST3160812AS (scsi)
Disk /dev/sda: 160GB
Sector size (logical/physical): 512B/512B
Partition Table: msdos

Number  Start   End     Size    Type      File system  Flags
 1      32.3kB  107MB   107MB   primary   ext3         boot
 2      107MB   105GB   105GB   primary   ext3
 3      105GB   107GB   2147MB  primary   linux-swap
 4      107GB   160GB   52.9GB  extended       root
 5      107GB   133GB   26.2GB  logical   ext3
 6      133GB   133GB   107MB   logical   ext3
 7      133GB   160GB   26.6GB  logical               lvm
```

The first line contains the disk type, manufacturer, model number and interface, and the second line displays the disk label type. The remaining output below the fourth line shows the partition table.

In the partition table, the *Minor* number is the partition **number**. For example, the partition with minor number 1 corresponds to **/dev/sda1**. The **Start** and **End** values are in megabytes. Valid **Type** are metadata, free, primary, extended, or logical. The **Filesystem** is the file system type, which can be any of the following:

- ext2
- ext3
- fat16
- fat32
- hfs
- jfs
- linux-swap
- ntfs
- reiserfs

- hp-ufs
- sun-ufs
- xfs

If a **Filesystem** of a device shows no value, this means that its file system type is unknown.

The **Flags** column lists the flags set for the partition. Available flags are boot, root, swap, hidden, raid, lvm, or lba.

Note

To select a different device without having to restart **parted**, use the **select** command followed by the device name (for example, **/dev/sda**). Doing so allows you to view or configure the partition table of a device.

13.2. Creating a Partition

Warning

Do not attempt to create a partition on a device that is in use.

Procedure 13.1. Creating a partition

1. Before creating a partition, boot into rescue mode (or unmount any partitions on the device and turn off any swap space on the device).
2. Start **parted**, where **/dev/*sda*** is the device on which to create the partition:

```
# parted /dev/sda
```

3. View the current partition table to determine if there is enough free space:

```
# print
```

If there is not enough free space, you can resize an existing partition. Refer to Section 13.4, “Resizing a Partition” for details.

13.2.1. Making the Partition

From the partition table, determine the start and end points of the new partition and what partition type it should be. You can only have four primary partitions (with no extended partition) on a device. If you need more than four partitions, you can have three primary partitions, one extended partition, and multiple logical partitions within the extended. For an overview of disk partitions, refer to the appendix *An Introduction to Disk Partitions* in the Red Hat Enterprise Linux 6 *Installation Guide*.

For example, to create a primary partition with an ext3 file system from 1024 megabytes until 2048 megabytes on a hard drive type the following command:

```
# mkpart primary ext3 1024 2048
```

Note

If you use the **mkpartfs** command instead, the file system is created after the partition is created. However, **parted** does not support creating an ext3 file system. Thus, if you wish to create an ext3 file system, use **mkpart** and create the file system with the **mkfs** command as described later.

The changes start taking place as soon as you press **Enter**, so review the command before executing to it.

After creating the partition, use the **print** command to confirm that it is in the partition table with the correct partition type, file system type, and size. Also remember the minor number of the new partition so that you can label any file systems on it. You should also view the output of **cat /proc/partitions** after parted is closed to make sure the kernel recognizes the new partition.

The maximum number of partitions parted will create is 128. While the *GUID Partition Table* (GPT) specification allows for more partitions by growing the area reserved for the partition table, common practice used by parted is to limit it to enough area for 128 partitions.

13.2.2. Formatting and Labeling the Partition

To format and label the partition use the following procedure:

Procedure 13.2. Format and label the partition

1. The partition still does not have a file system. To create one use the following command:

   ```
   # /sbin/mkfs -t ext3 /dev/sda6
   ```

   Warning

   Formatting the partition permanently destroys any data that currently exists on the partition.

2. Next, give the file system on the partition a label. For example, if the file system on the new partition is **/dev/sda6** and you want to label it **/work**, use:

   ```
   # e2label /dev/sda6 /work
   ```

By default, the installation program uses the mount point of the partition as the label to make sure the label is unique. You can use any label you want.

Afterwards, create a mount point (e.g. **/work**) as root.

13.2.3. Add to /etc/fstab

As root, edit the **/etc/fstab** file to include the new partition using the partition's UUID. Use the command **blkid -o list** for a complete list of the partition's UUID, or **blkid device** for individual device details.

The first column should contain **UUID=** followed by the file system's UUID. The second column should contain the mount point for the new partition, and the next column should be the file system type (for example, ext3 or swap). If you need more information about the format, read the man page with the command **man fstab**.

If the fourth column is the word **defaults**, the partition is mounted at boot time. To mount the partition without rebooting, as root, type the command:

```
mount /work
```

13.3. Removing a Partition

Warning

Do not attempt to remove a partition on a device that is in use.

Procedure 13.3. Remove a partition

1. Before removing a partition, boot into rescue mode (or unmount any partitions on the device and turn off any swap space on the device).
2. Start **parted**, where **/dev/*sda*** is the device on which to remove the partition:

   ```
   # parted /dev/sda
   ```

3. View the current partition table to determine the minor number of the partition to remove:

   ```
   # print
   ```

4. Remove the partition with the command **rm**. For example, to remove the partition with minor number 3:

   ```
   # rm 3
   ```

   The changes start taking place as soon as you press **Enter**, so review the command before committing to it.

5. After removing the partition, use the **print** command to confirm that it is removed from the partition table. You should also view the output of **/proc/partitions** to make sure the kernel knows the partition is removed.

   ```
   # cat /proc/partitions
   ```

6. The last step is to remove it from the **/etc/fstab** file. Find the line that declares the removed partition, and remove it from the file.

13.4. Resizing a Partition

Warning

Do not attempt to resize a partition on a device that is in use.

Procedure 13.4. Resize a partition

1. Before resizing a partition, boot into rescue mode (or unmount any partitions on the device and turn off any swap space on the device).
2. Start **parted**, where **/dev/*sda*** is the device on which to resize the partition:

```
# parted /dev/sda
```

3. View the current partition table to determine the minor number of the partition to resize as well as the start and end points for the partition:

```
# print
```

4. To resize the partition, use the **resize** command followed by the minor number for the partition, the starting place in megabytes, and the end place in megabytes.

> **Example 13.2. Resize a partition**
>
> For example:
>
> **resize *3 1024 2048***

Warning

A partition cannot be made larger than the space available on the device

5. After resizing the partition, use the **print** command to confirm that the partition has been resized correctly, is the correct partition type, and is the correct file system type.
6. After rebooting the system into normal mode, use the command **df** to make sure the partition was mounted and is recognized with the new size.

Chapter 14. LVM (Logical Volume Manager)

LVM is a tool for logical volume management which includes allocating disks, striping, mirroring and resizing logical volumes.

With LVM, a hard drive or set of hard drives is allocated to one or more *physical volumes*. LVM physical volumes can be placed on other block devices which might span two or more disks.

The physical volumes are combined into *logical volumes*, with the exception of the **/boot/** partition. The **/boot/** partition cannot be on a logical volume group because the boot loader cannot read it. If the root (/) partition is on a logical volume, create a separate **/boot/** partition which is not a part of a volume group.

Since a physical volume cannot span over multiple drives, to span over more than one drive, create one or more physical volumes per drive.

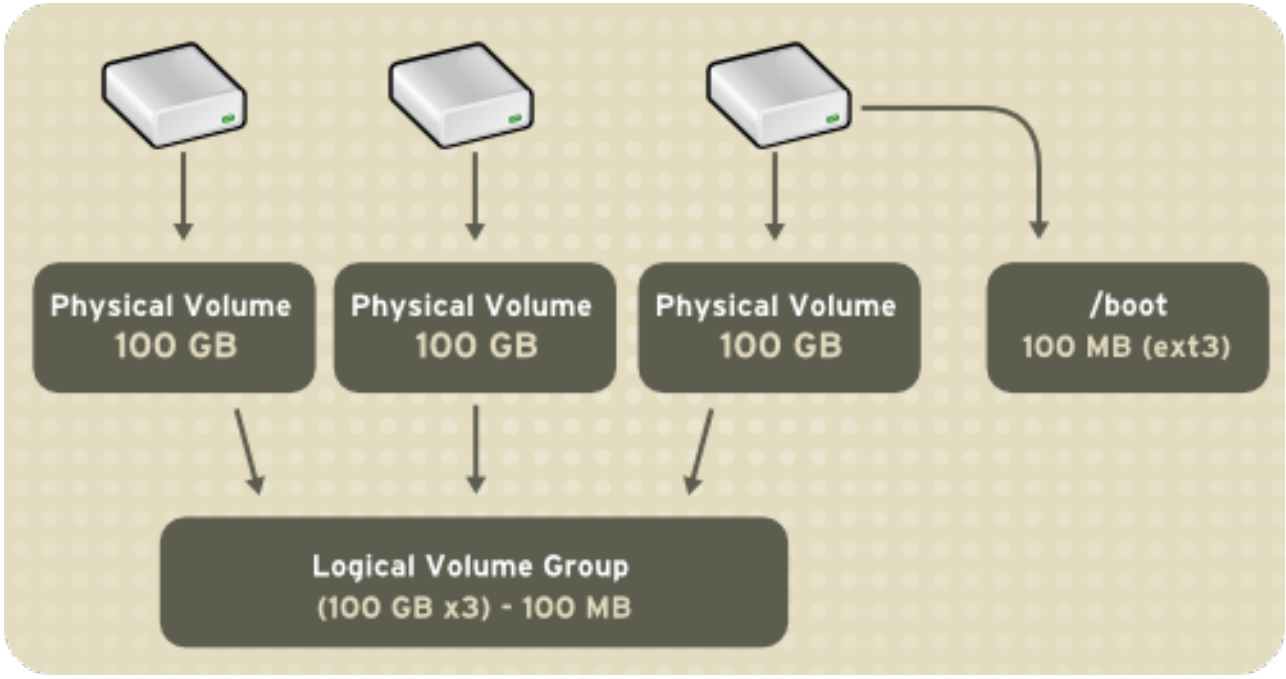


Figure 14.1. Logical Volumes

The volume groups can be divided into *logical volumes*, which are assigned mount points, such as **/home** and **/** and file system types, such as ext2 or ext3. When "partitions" reach their full capacity, free space from the volume group can be added to the logical volume to increase the size of the partition. When a new hard drive is added to the system, it can be added to the volume group, and partitions that are logical volumes can be increased in size.

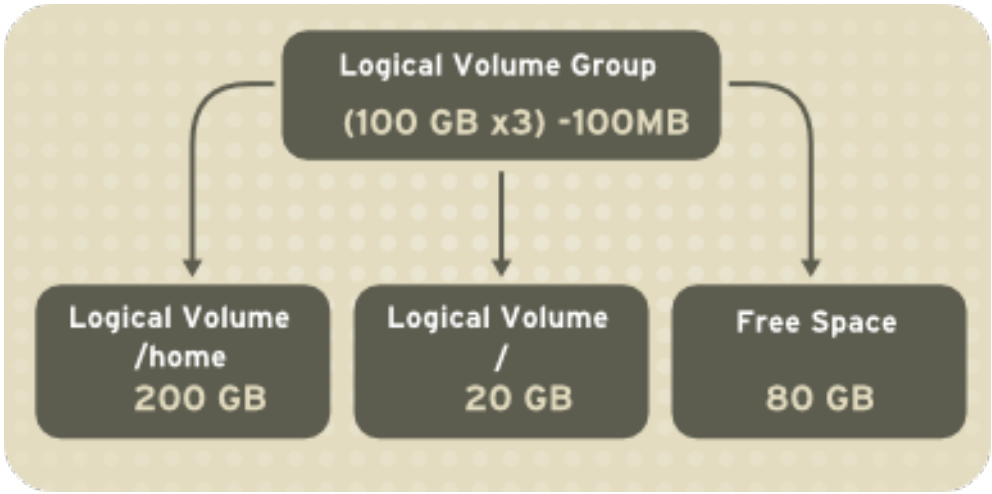


Figure 14.2. Logical Volumes

On the other hand, if a system is partitioned with the ext3 file system, the hard drive is divided into partitions of defined sizes. If a partition becomes full, it is not easy to expand the size of the partition. Even if the partition is moved to another hard drive, the original hard drive space has to be reallocated as a different partition or not used.

Important

This chapter on LVM/LVM2 focuses on the use of the LVM GUI administration tool, i.e. **`system-config-lvm`**. For comprehensive information on the creation and configuration of LVM partitions in clustered and non-clustered storage, refer to the *Logical Volume Manager Administration* guide also provided by Red Hat.

In addition, the *Installation Guide* for Red Hat Enterprise Linux 6 also documents how to create and configure LVM logical volumes during installation. For more information, refer to the *Create LVM Logical Volume* section of the *Installation Guide* for Red Hat Enterprise Linux 6.

14.1. What is LVM2?

LVM version 2, or LVM2, was the default for Red Hat Enterprise Linux 5, which uses the device mapper driver contained in the 2.6 kernel. LVM2 can be upgraded from versions of Red Hat Enterprise Linux running the 2.4 kernel.

14.2. Using `system-config-lvm`

The LVM utility allows you to manage logical volumes within X windows or graphically. It does not come pre-installed, so to install it first run:

```
# yum install system-config-lvm
```

You can then access the application by selecting from your menu panel **System → Administration → Logical Volume Management**. Alternatively you can start the Logical Volume Management utility by typing **`system-config-lvm`** from a terminal.

In the example used in this section, the following are the details for the volume group that was created during the installation:

Example 14.1. Creating a volume group at installation

```
/boot - (Ext3) file system. Displayed under 'Uninitialized Entities'.
(DO NOT initialize this partition).
LogVol00 - (LVM) contains the (/) directory (312 extents).
LogVol02 - (LVM) contains the (/home) directory (128 extents).
LogVol03 - (LVM) swap (28 extents).
```

The logical volumes above were created in disk entity **/dev/hda2** while **/boot** was created in **/dev/hda1**. The system also consists of 'Uninitialised Entities' which are illustrated in Example 14.2, “Uninitialized entries”. The figure below illustrates the main window in the LVM utility. The logical and the physical views of the above configuration are illustrated below. The three logical volumes exist on the same physical volume (hda2).

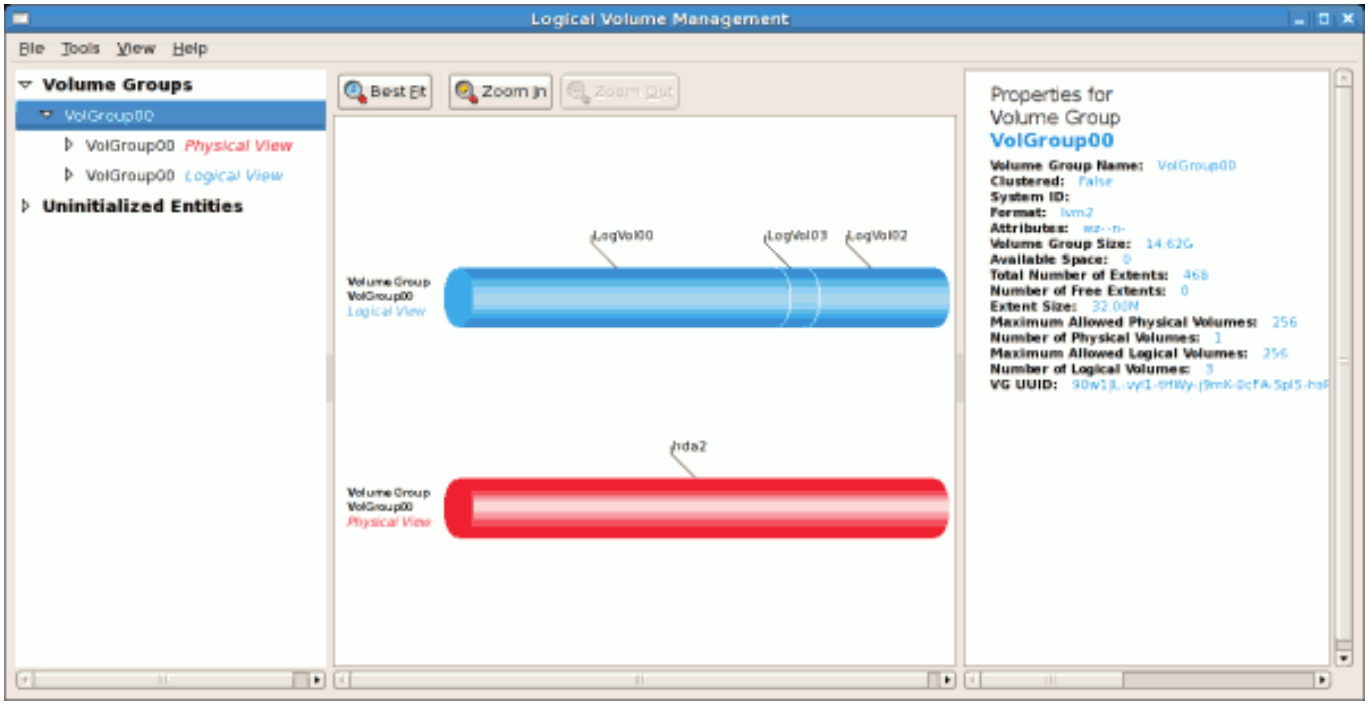


Figure 14.3. Main LVM Window

The figure below illustrates the physical view for the volume. In this window, you can select and remove a volume from the volume group or migrate extents from the volume to another volume group. Steps to migrate extents are discussed in Figure 14.10, “Migrate Extents”.

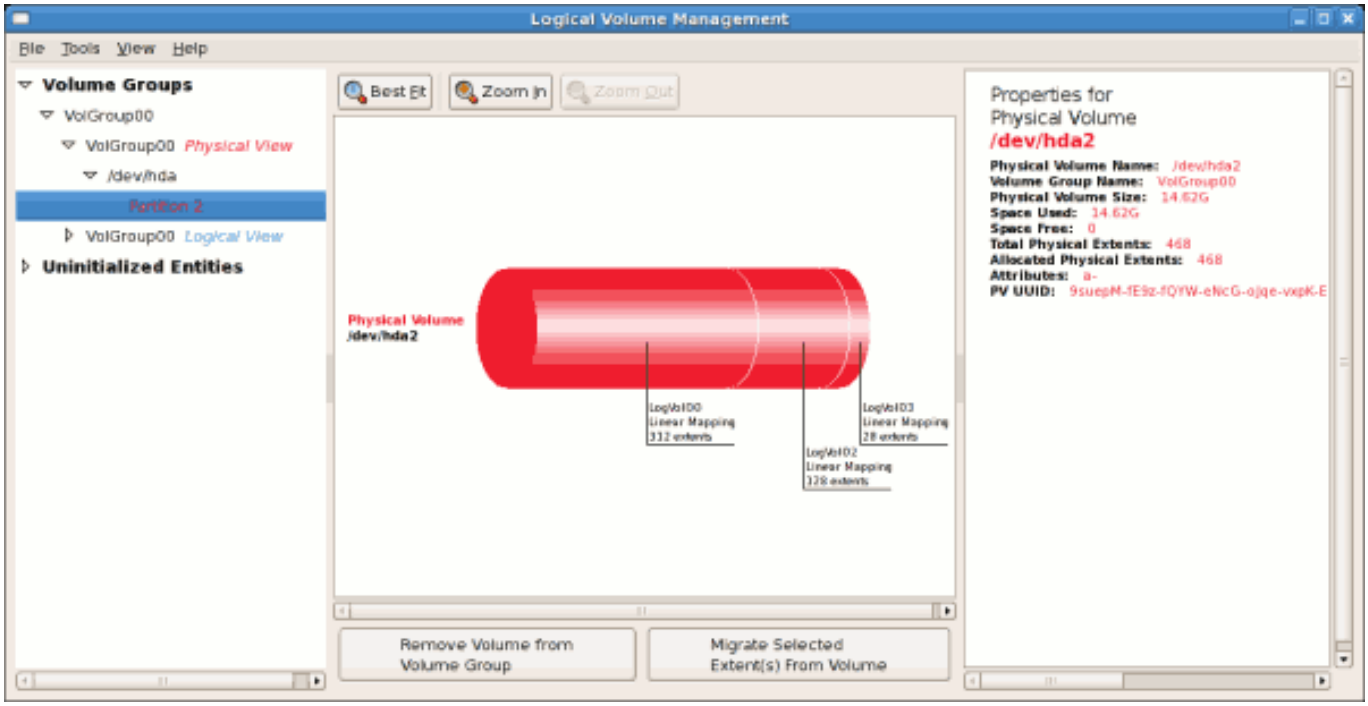


Figure 14.4. Physical View Window

The figure below illustrates the logical view for the selected volume group. The individual logical volume sizes are also illustrated.

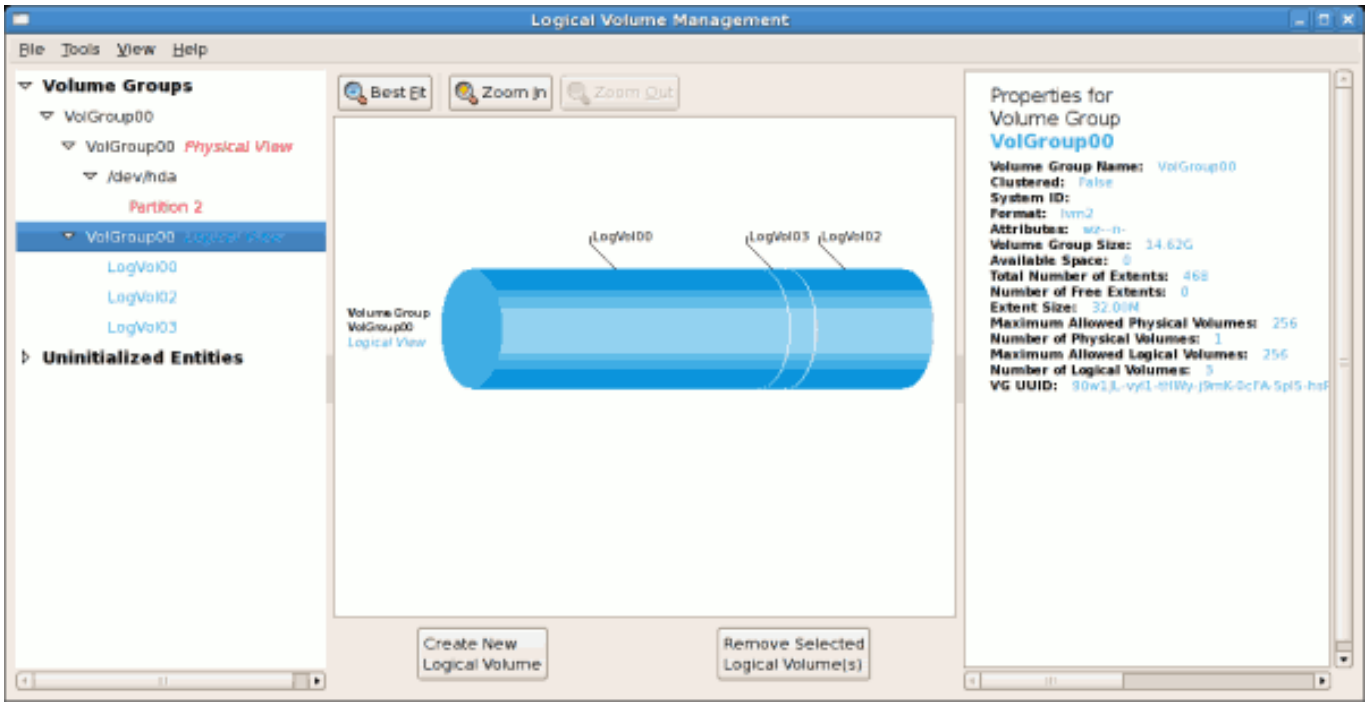


Figure 14.5. Logical View Window

On the left side column, you can select the individual logical volumes in the volume group to view more details about each. In this example the objective is to rename the logical volume name for 'LogVol03' to 'Swap'. To perform this operation select the respective logical volume from the list (as opposed to the image) and click on the **`Edit Properties`** button. This will display the Edit Logical

Volume window from which you can modify the Logical volume name, size (in extents, gigabytes, megabytes, or kilobytes) and also use the remaining space available in a logical volume group. The figure below illustrates this.

This logical volume cannot be changed in size as there is currently no free space in the volume group. If there was remaining space, this option would be enabled (see Figure 14.17, "Edit logical volume"). Click on the **OK** button to save your changes (this will remount the volume). To cancel your changes click on the **Cancel** button. To revert to the last snapshot settings click on the **Revert** button. A snapshot can be created by clicking on the **Create Snapshot** button on the LVM utility window. If the selected logical volume is in use by the system, the root directory for example, this task will not be successful as the volume cannot be unmounted.

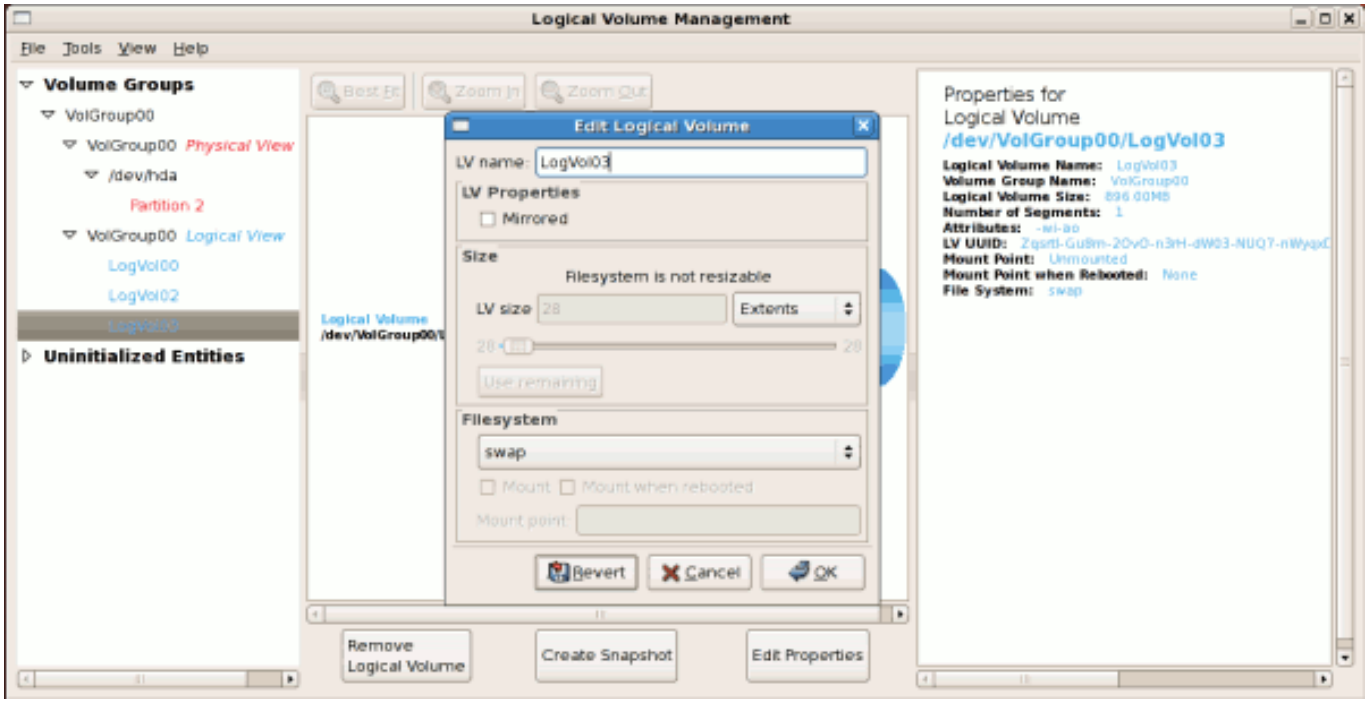
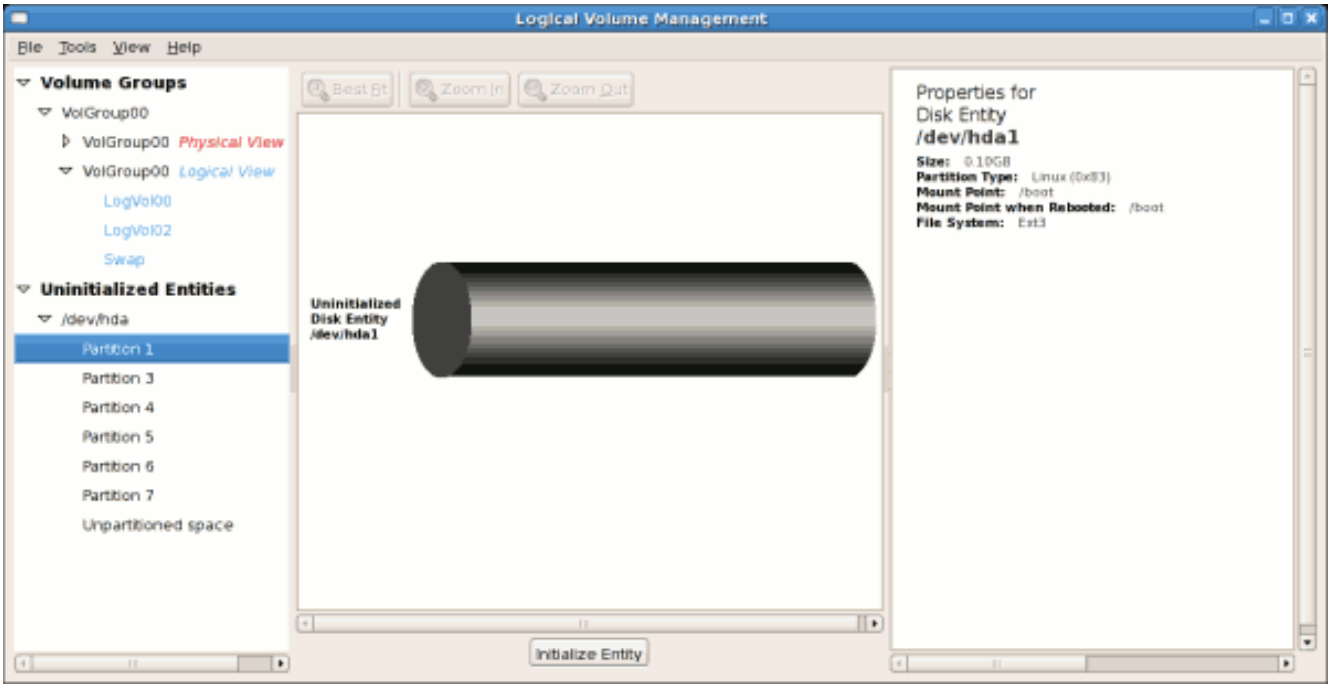


Figure 14.6. Edit Logical Volume

14.2.1. Utilizing Uninitialized Entities

'Uninitialized Entities' consist of unpartitioned space and non LVM file systems. In this example partitions 3, 4, 5, 6 and 7 were created during installation and some unpartitioned space was left on the hard disk. View each partition and ensure that you read the 'Properties for Disk Entity' on the right column of the window to ensure that you do not delete critical data. In this example partition 1 cannot be initialized as it is **/boot**. Uninitialized entities are illustrated below.

Example 14.2. Uninitialized entries



In this example, partition 3 will be initialized and added to an existing volume group. To initialize a partition or unpartioned space, select the partition and click on the **`Initialize Entity`** button. Once initialized, a volume will be listed in the 'Unallocated Volumes' list.

14.2.2. Adding Unallocated Volumes to a Volume Group

Once initialized, a volume will be listed in the 'Unallocated Volumes' list. The figure below illustrates an unallocated partition (Partition 3). The respective buttons at the bottom of the window allow you to:

- create a new volume group,
- add the unallocated volume to an existing volume group,
- remove the volume from LVM.

To add the volume to an existing volume group, click on the **`Add to Existing Volume Group`** button.

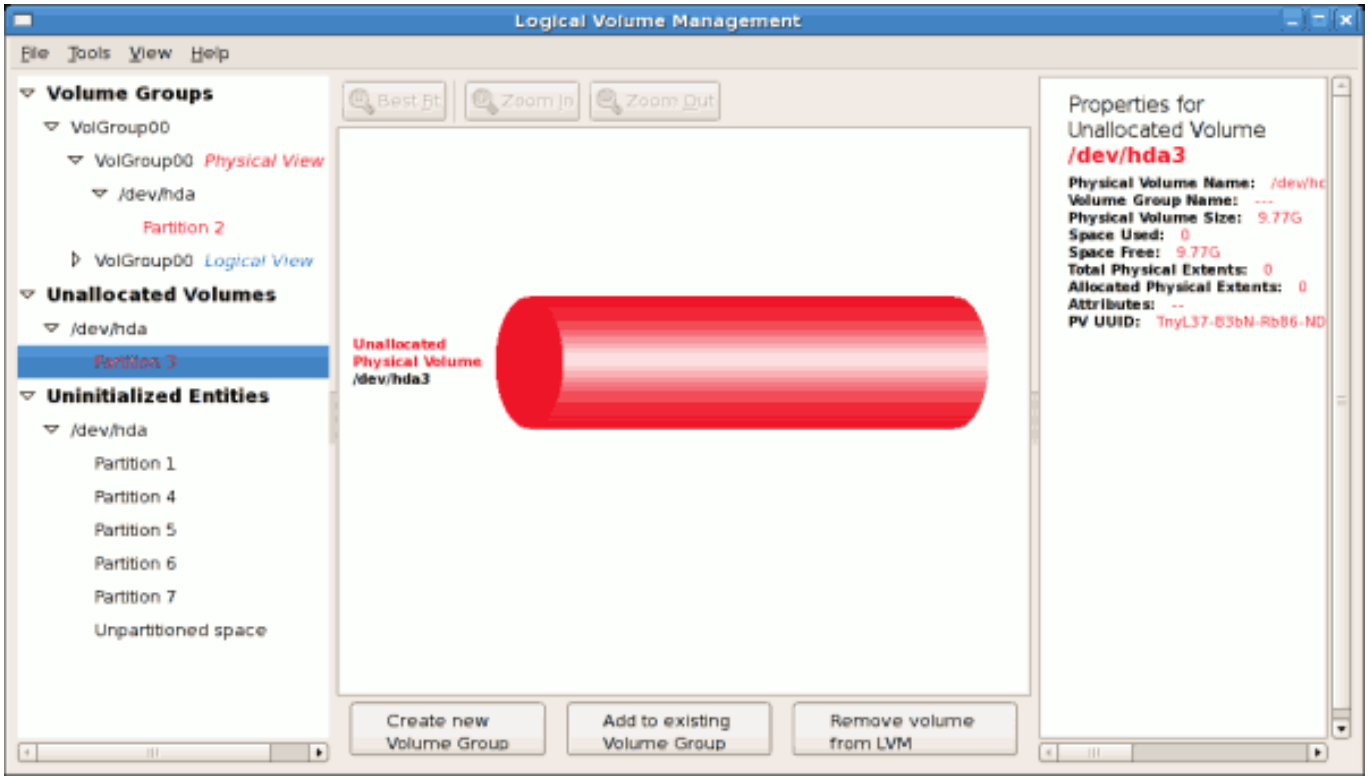
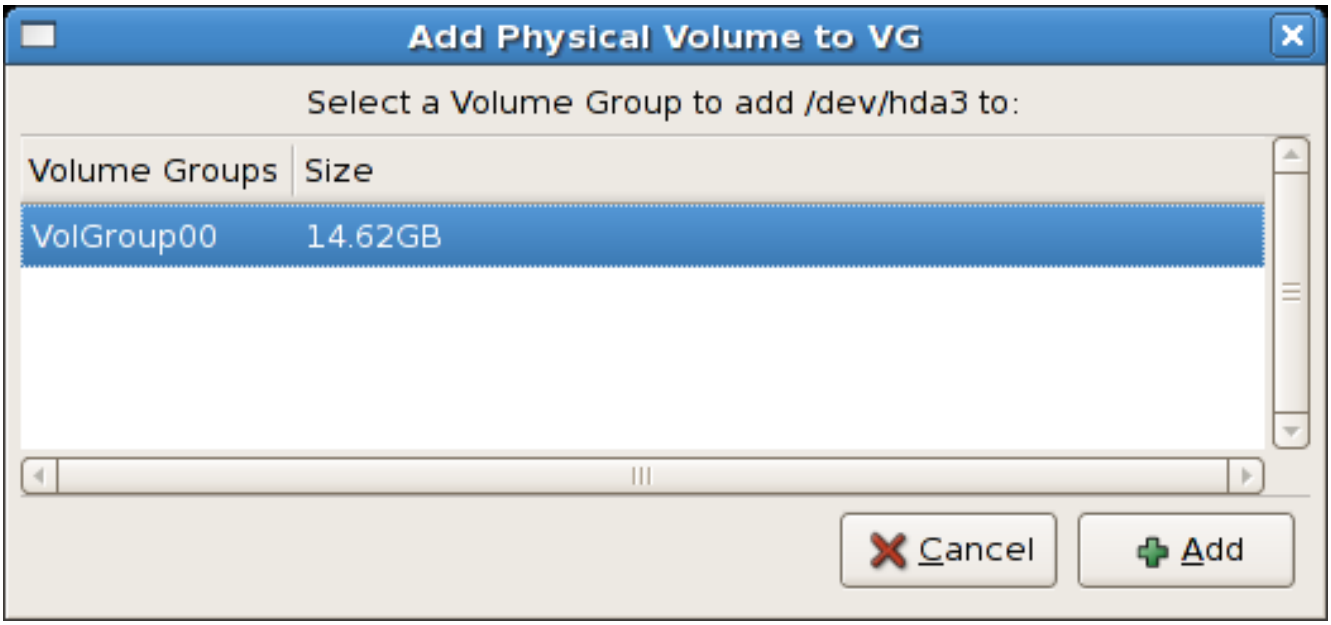


Figure 14.7. Unallocated Volumes

Clicking on the **Add to Existing Volume Group** button will display a pop-up window listing the existing volume groups to which you can add the physical volume you are about to initialize. A volume group may span across one or more hard disks.

Example 14.3. Add a physical volume to volume group

In this example only one volume group exists as illustrated below.



Once added to an existing volume group the new logical volume is automatically added to the unused space of the selected volume group. You can use the unused space to:

- create a new logical volume (click on the **Create New Logical Volume(s)** button),

- select one of the existing logical volumes and increase the extents (see Section 14.2.6, “Extending a Volume Group”),
- select an existing logical volume and remove it from the volume group by clicking on the **Remove Selected Logical Volume(s)** button. You cannot select unused space to perform this operation.

The figure below illustrates the logical view of 'VolGroup00' after adding the new volume group.

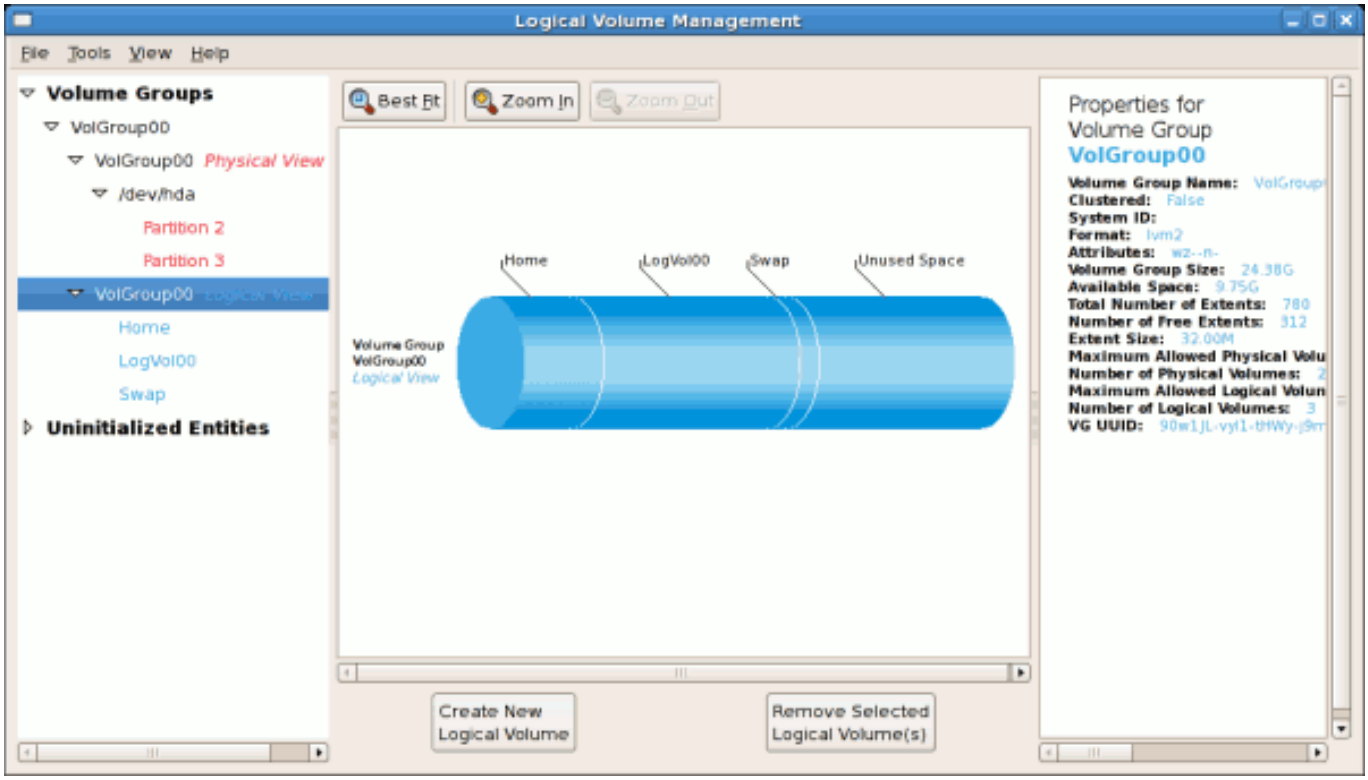


Figure 14.8. Logical view of volume group

In the figure below, the uninitialized entities (partitions 3, 5, 6 and 7) were added to 'VolGroup00'.

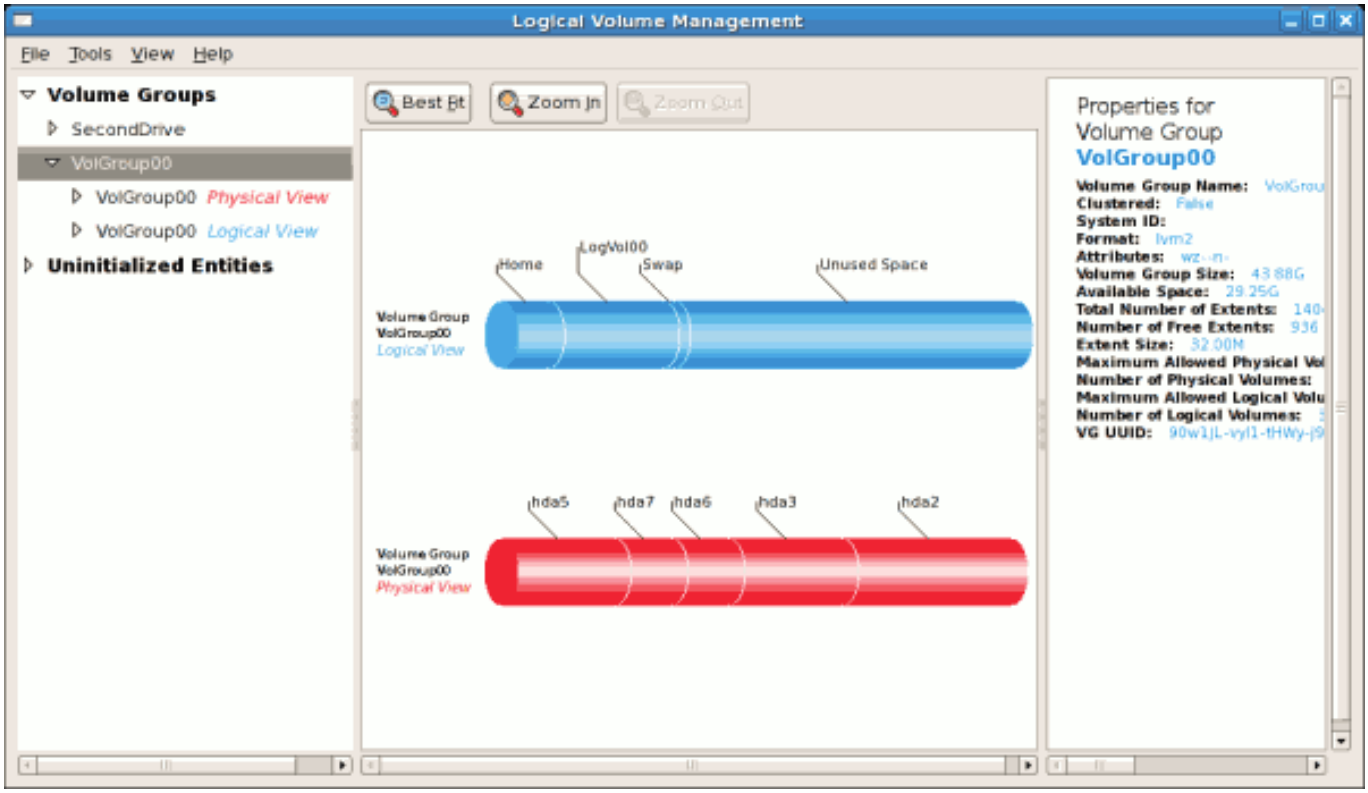


Figure 14.9. Logical view of volume group

14.2.3. Migrating Extents

To migrate extents from a physical volume, select the volume from the list in the left pane, highlight the desired extents in the central window, and click on the **Migrate Selected Extent(s) From Volume** button. You need to have a sufficient number of free extents to migrate extents within a volume group. An error message will be displayed if you do not have a sufficient number of free extents. To resolve this problem, extend your volume group (see Section 14.2.6, “Extending a Volume Group”). If a sufficient number of free extents is detected in the volume group, a pop-up window will be displayed from which you can select the destination for the extents or automatically let LVM choose the physical volumes (PVs) to migrate them to. This is illustrated below.

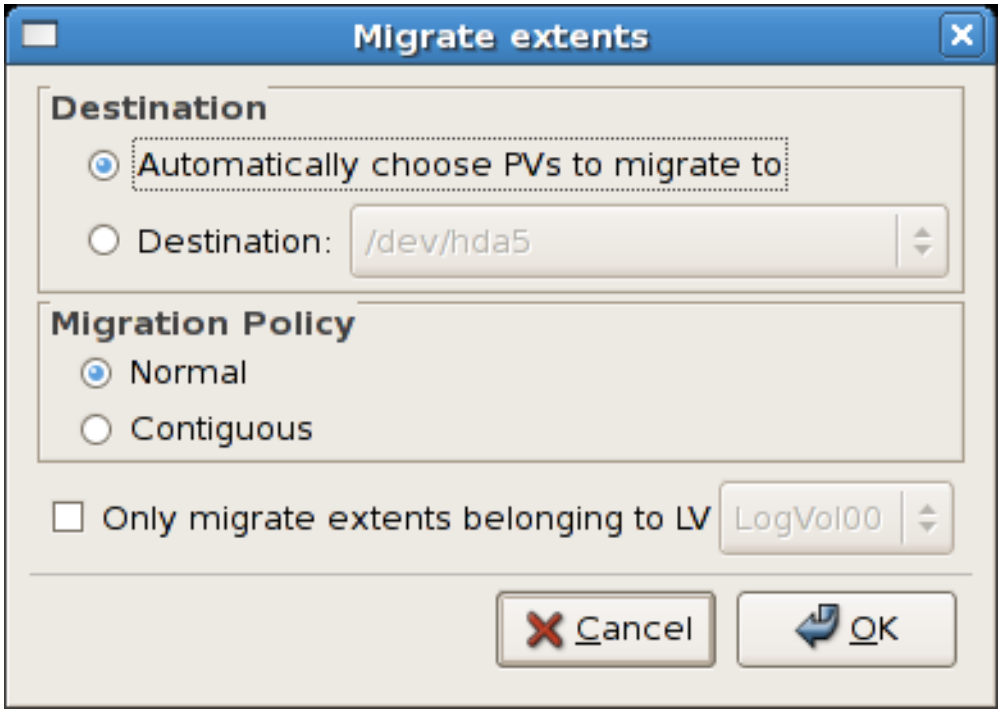


Figure 14.10. Migrate Extents

The figure below illustrates a migration of extents in progress. In this example, the extents were migrated to 'Partition 3'.

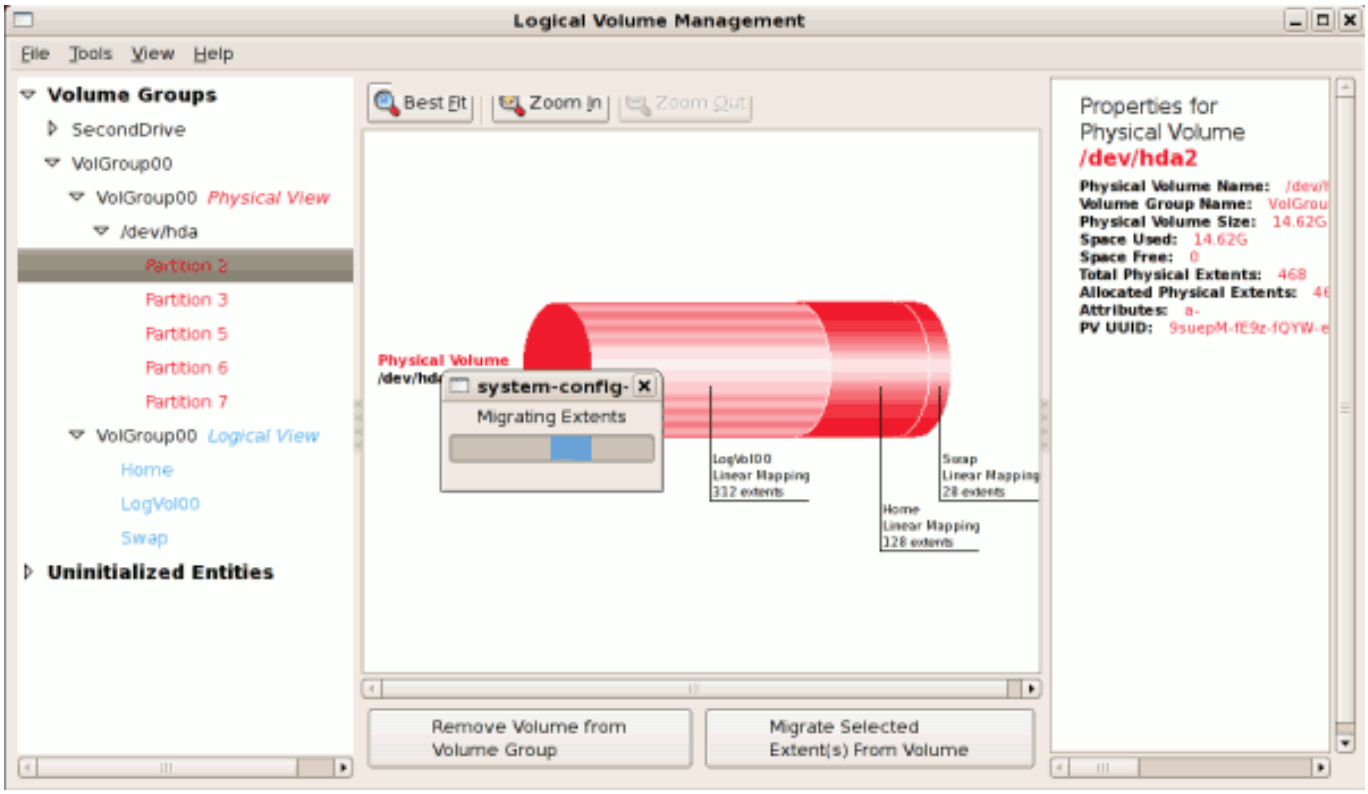


Figure 14.11. Migrating extents in progress

Once the extents have been migrated, unused space is left on the physical volume. The figure below illustrates the physical and logical view for the volume group. The extents of LogVol00 which were initially in hda2 are now in hda3. Migrating extents allows you to move logical volumes in case of hard disk upgrades or to manage your disk space better.

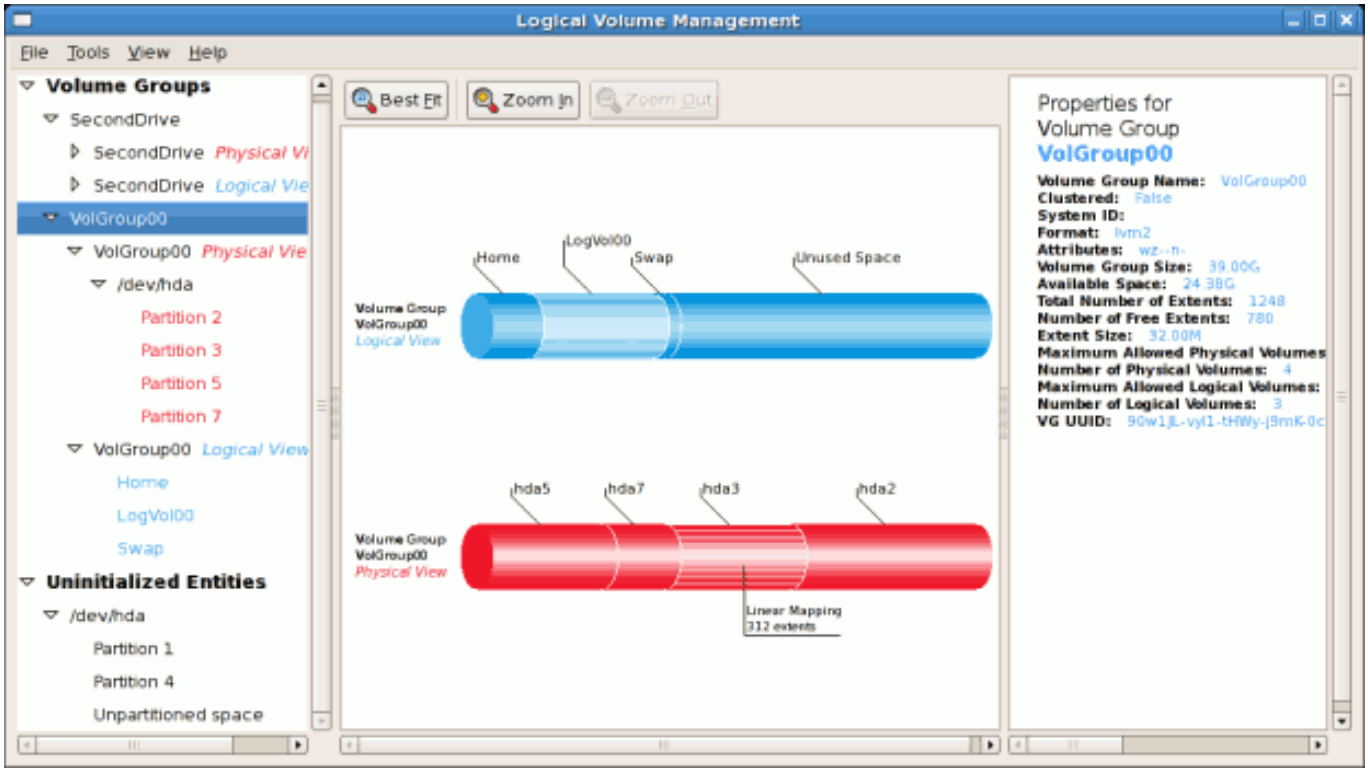


Figure 14.12. Logical and physical view of volume group

14.2.4. Adding a New Hard Disk Using LVM

In this example, a new IDE hard disk was added. The figure below illustrates the details for the new hard disk. From the figure below, the disk is uninitialized and not mounted. To initialize a partition, click on the **`Initialize Entity`** button. For more details, see Section 14.2.1, "Utilizing Uninitialized Entities". Once initialized, LVM will add the new volume to the list of unallocated volumes as illustrated in Example 14.4, "Create a new volume group".

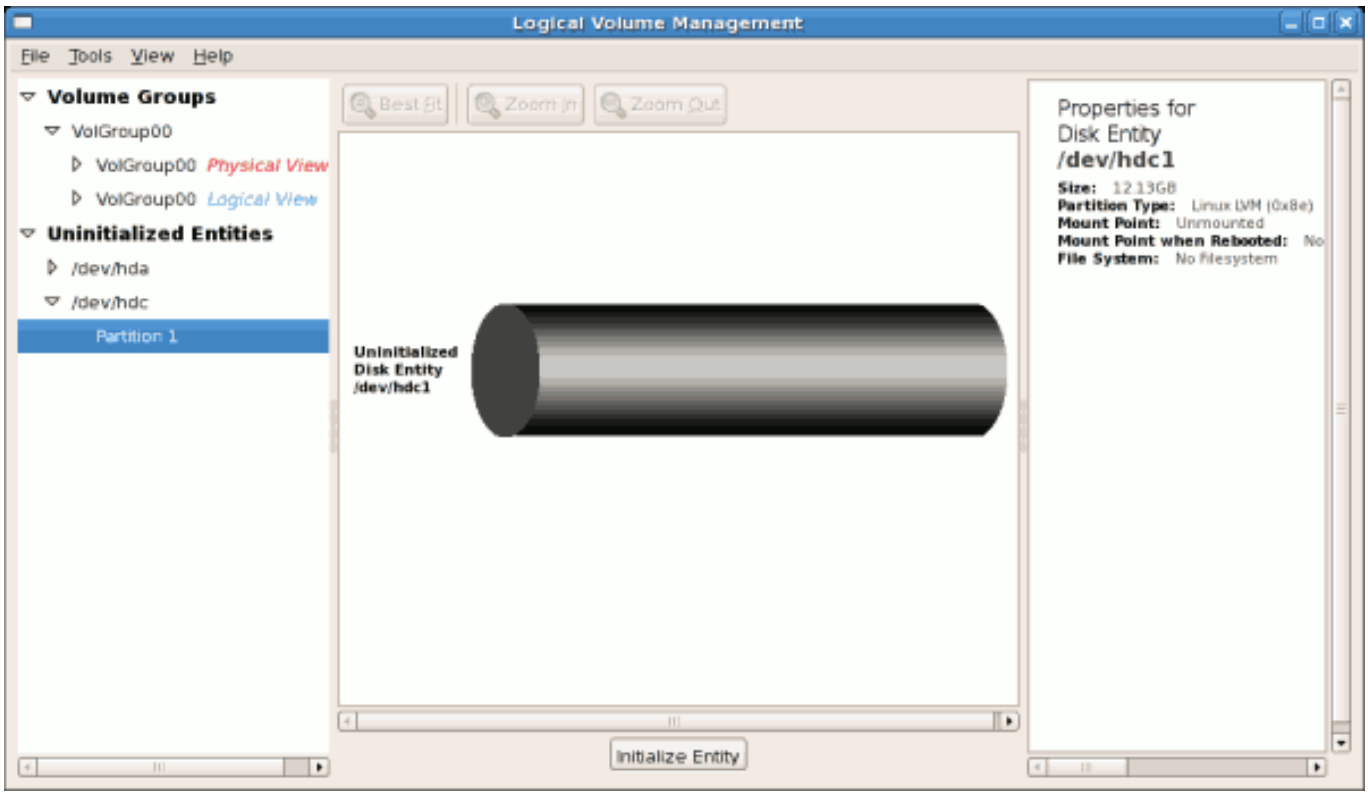


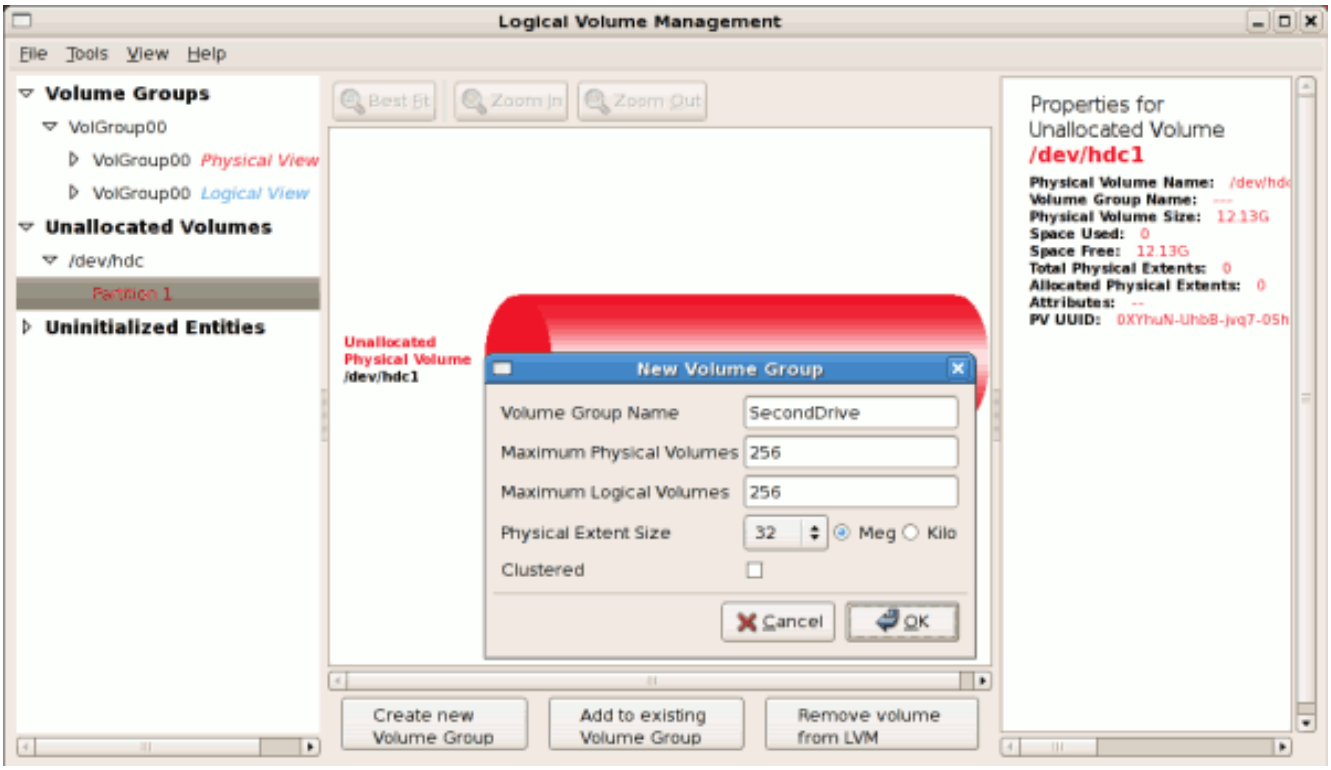
Figure 14.13. Uninitialized hard disk

14.2.5. Adding a New Volume Group

Once initialized, LVM will add the new volume to the list of unallocated volumes where you can add it to an existing volume group or create a new volume group. You can also remove the volume from LVM. If the volume is removed from LVM, it will be added to the 'Uninitialized Entities' list, as illustrated in Figure 14.13, “Uninitialized hard disk”.

Example 14.4. Create a new volume group

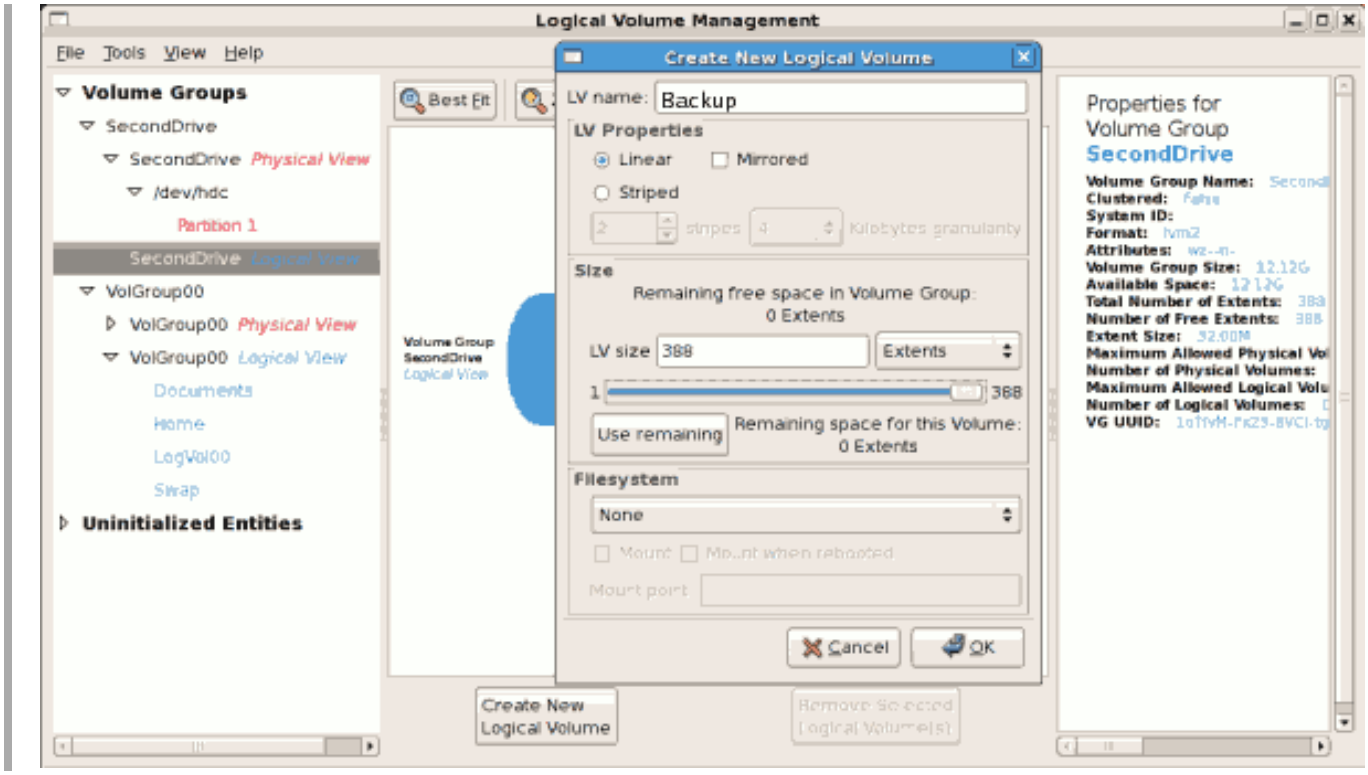
In this example, a new volume group was created as illustrated below.



Once created a new volume group will be displayed in the list of existing volume groups as illustrated below. The logical view will display the new volume group with unused space as no logical volumes have been created. To create a logical volume, select the volume group and click on the **`Create New Logical Volume`** button as illustrated below. Select the extents you wish to use on the volume group.

Example 14.5. Select the extents

In this example, all the extents in the volume group were used to create the new logical volume.



The figure below illustrates the physical view of the new volume group. The new logical volume named 'Backups' in this volume group is also listed.

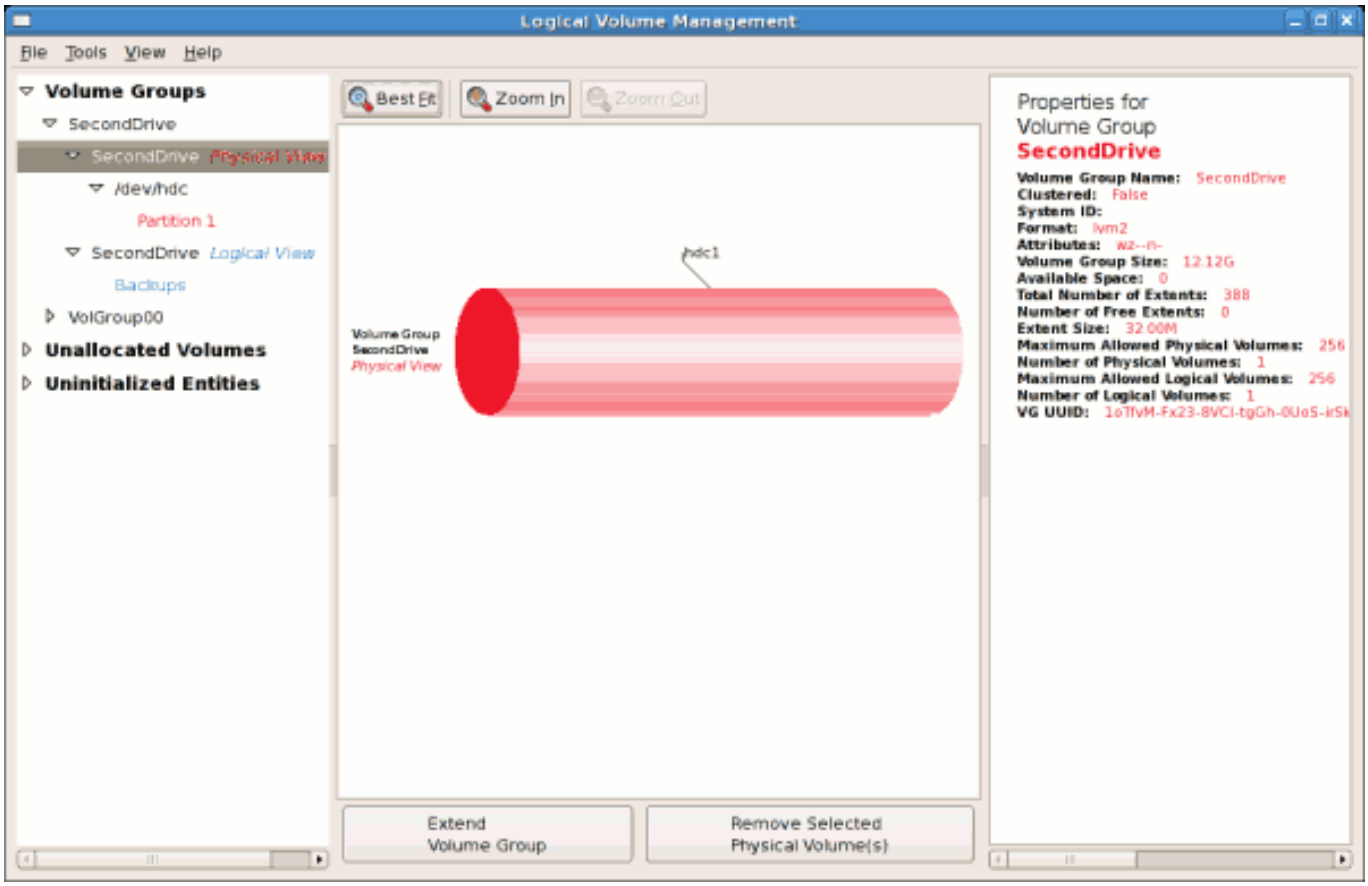


Figure 14.14. Physical view of new volume group

14.2.6. Extending a Volume Group

In this example, the objective was to extend the new volume group to include an uninitialized entity (partition). Doing so increases the size or number of extents for the volume group. To extend the volume group, ensure that on the left pane the Physical View option is selected within the desired Volume Group. Then click on the **Extend Volume Group** button. This will display the 'Extend Volume Group' window as illustrated below. On the 'Extend Volume Group' window, you can select disk entities (partitions) to add to the volume group. Ensure that you check the contents of any 'Uninitialized Disk Entities' (partitions) to avoid deleting any critical data (see Figure 14.13, “Uninitialized hard disk”). In the example, the disk entity (partition) **/dev/hda6** was selected as illustrated below.

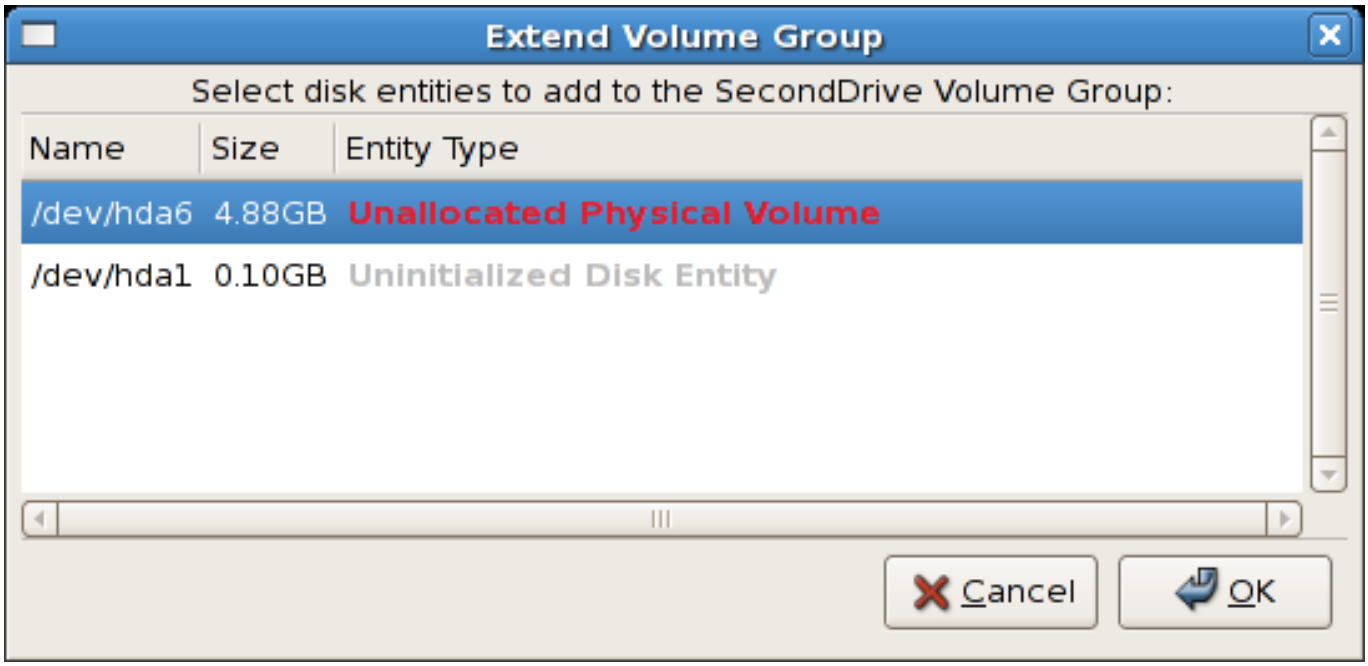


Figure 14.15. Select disk entities

Once added, the new volume will be added as 'Unused Space' in the volume group. The figure below illustrates the logical and physical view of the volume group after it was extended.

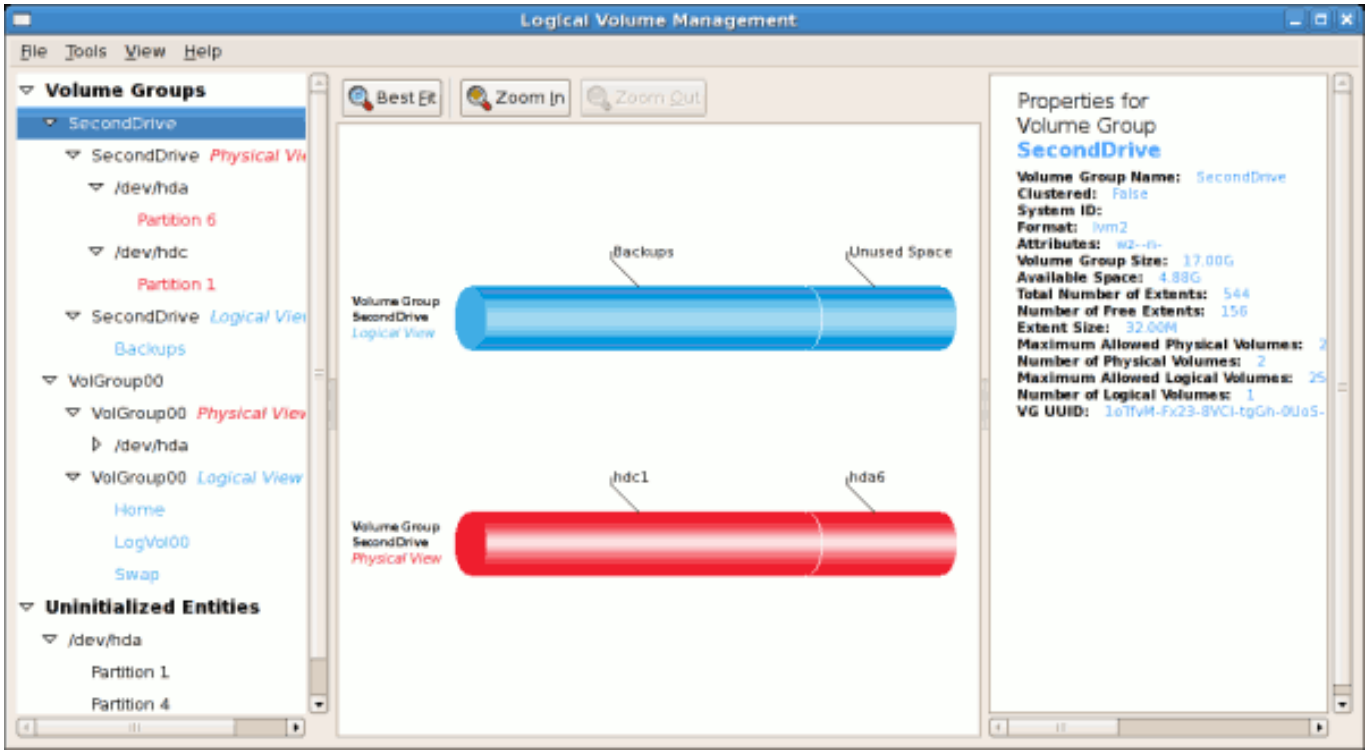


Figure 14.16. Logical and physical view of an extended volume group

14.2.7. Editing a Logical Volume

The LVM utility allows you to select a logical volume in the volume group and modify its name, size and specify file system options. In this example, the logical volume named 'Backups" was extended onto the remaining space for the volume group.

Clicking on the **`Edit Properties`** button will display the 'Edit Logical Volume' pop-up window from which you can edit the properties of the logical volume. On this window, you can also mount the volume after making the changes and mount it when the system is rebooted. You should indicate the mount point. If the mount point you specify does not exist, a pop-up window will be displayed prompting you to create it. The 'Edit Logical Volume' window is illustrated below.

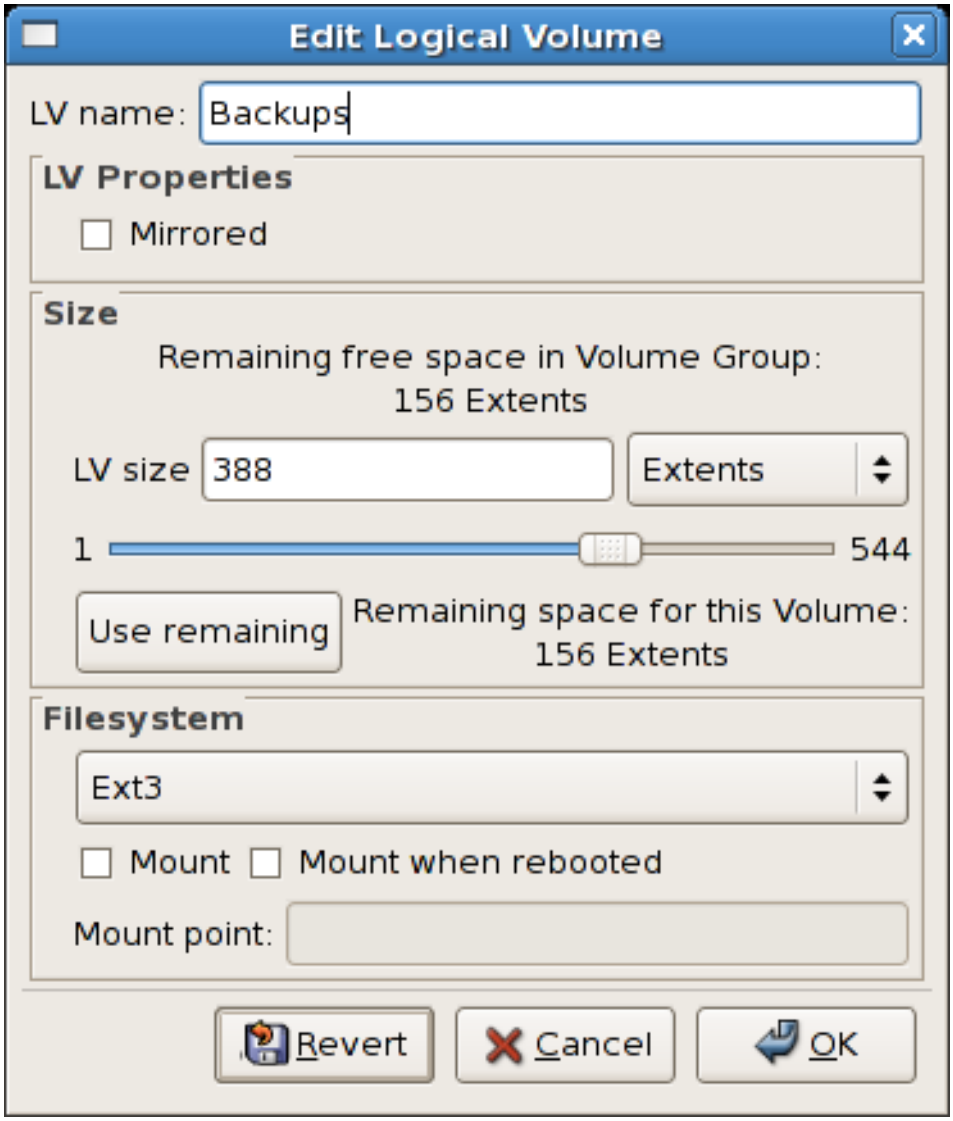


Figure 14.17. Edit logical volume

If you wish to mount the volume, select the 'Mount' checkbox indicating the preferred mount point. To mount the volume when the system is rebooted, select the 'Mount when rebooted' checkbox. In this example, the new volume will be mounted in **/mnt/backups**. This is illustrated in the figure below.

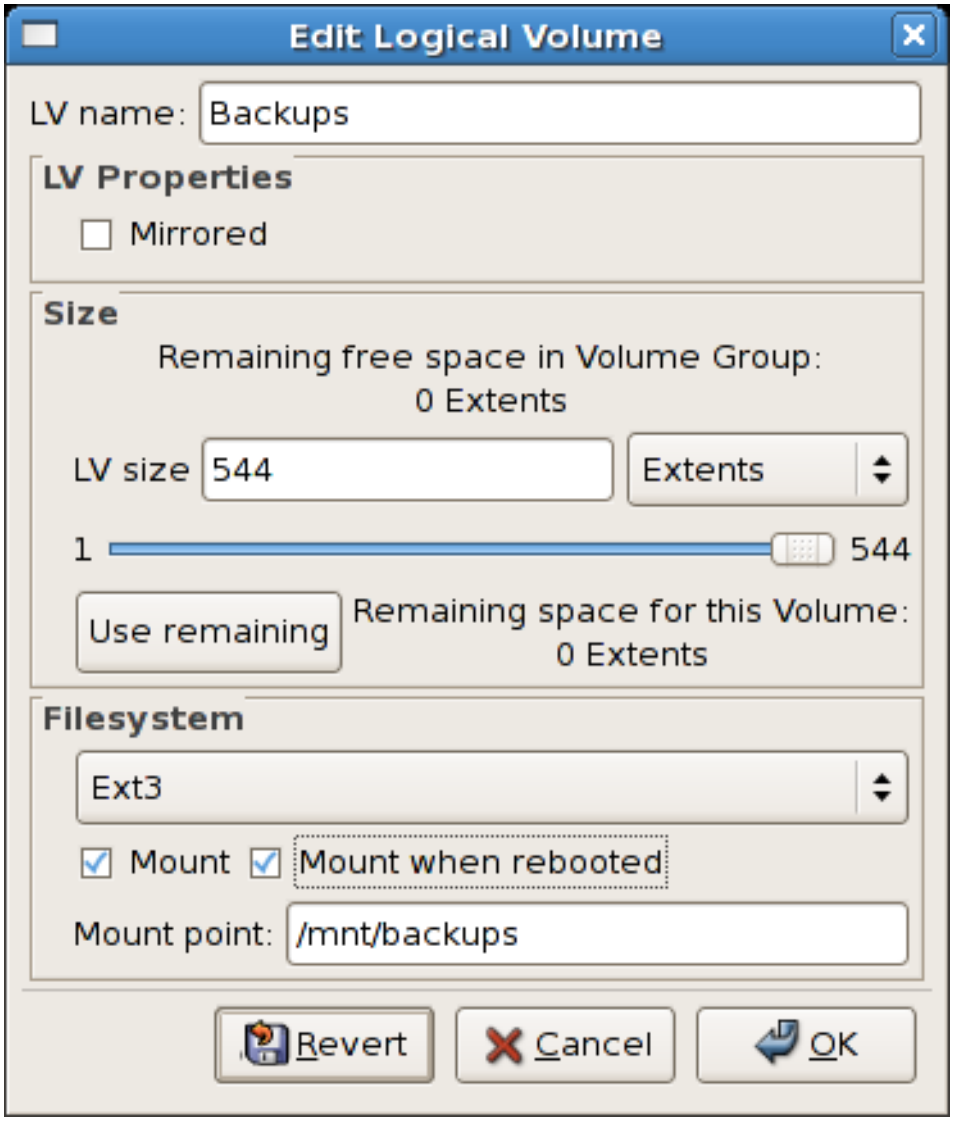


Figure 14.18. Edit logical volume - specifying mount options

The figure below illustrates the logical and physical view of the volume group after the logical volume was extended to the unused space. In this example that the logical volume named 'Backups' spans across two hard disks. A volume can be stripped across two or more physical devices using LVM.

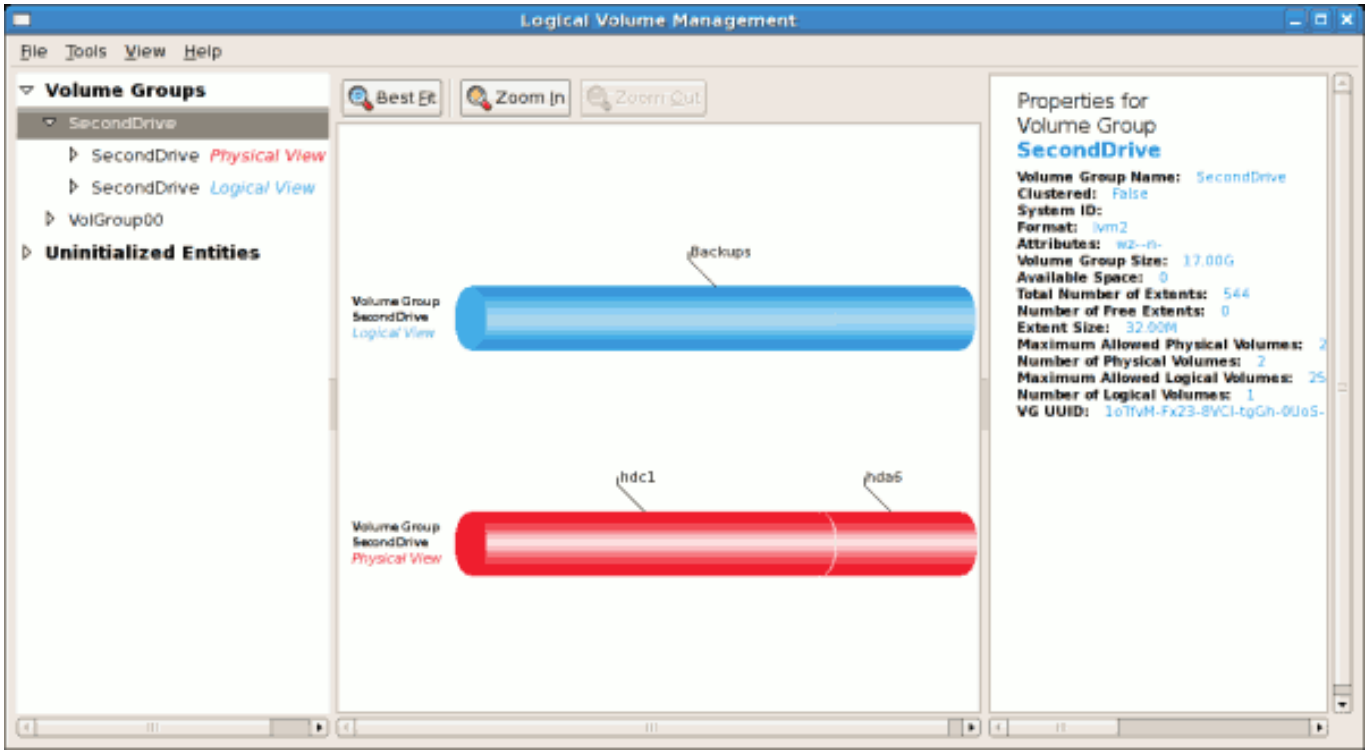


Figure 14.19. Edit logical volume

14.3. LVM References

Use these sources to learn more about LVM.

Installed Documentation

- **`rpm -qd lvm2`** — This command shows all the documentation available from the **`lvm`** package, including man pages.
- **`lvm help`** — This command shows all LVM commands available.

Useful Websites

- http://sources.redhat.com/lvm2 — LVM2 webpage, which contains an overview, link to the mailing lists, and more.
- http://tldp.org/HOWTO/LVM-HOWTO/ — LVM HOWTO from the Linux Documentation Project.

Chapter 15. Swap Space

Swap space in Linux is used when the amount of physical memory (RAM) is full. If the system needs more memory resources and the RAM is full, inactive pages in memory are moved to the swap space. While swap space can help machines with a small amount of RAM, it should not be considered a replacement for more RAM. Swap space is located on hard drives, which have a slower access time than physical memory.

Swap space can be a dedicated swap partition (recommended), a swap file, or a combination of swap partitions and swap files.

Swap should equal 2x physical RAM for up to 2 GB of physical RAM, and then an additional 1x physical RAM for any amount above 2 GB, but never less than 32 MB.

Example 15.1. Swap RAM

So, if:

M = Amount of RAM in GB, and S = Amount of swap in GB, then

```
If M < 2
 S = M *2
Else
 S = M + 2
```

Using this formula, a system with 2 GB of physical RAM would have 4 GB of swap, while one with 3 GB of physical RAM would have 5 GB of swap. Creating a large swap space partition can be especially helpful if you plan to upgrade your RAM at a later time.

For systems with really large amounts of RAM (more than 32 GB) you can likely get away with a smaller swap partition (around 1x, or less, of physical RAM).

Important

File systems and LVM2 volumes assigned as swap space *should not* be in use when being modified. Any attempts to modify swap will fail if a system process or the kernel is using swap space. Use the **free** and **cat /proc/swaps** commands to verify how much and where swap is in use.

Red Hat advises that you modify swap space while the system is booted in *rescue* mode; for instructions on how to boot in *rescue mode*, refer to Red Hat's *Installation Guide*. When prompted to mount the file system, select **Skip**.

15.1. Adding Swap Space

Sometimes it is necessary to add more swap space after installation. For example, you may upgrade the amount of RAM in your system from 1 GB to 2 GB, but there is only 2 GB of swap space. It might be advantageous to increase the amount of swap space to 4 GB if you perform memory-intense operations or run applications that require a large amount of memory.

You have three options: create a new swap partition, create a new swap file, or extend swap on an

existing LVM2 logical volume. It is recommended that you extend an existing logical volume.

15.1.1. Extending Swap on an LVM2 Logical Volume

By default, Red Hat Enterprise Linux 6 uses all available space during installation. If this is the case with your system, then you must first add a new physical volume to the volume group used by the swap space. For instructions on how to do so, refer to Section 14.2.2, “Adding Unallocated Volumes to a Volume Group”.

After adding additional storage to the swap space's volume group, it is now possible to extend it. To do so, perform the following procedure (assuming **/dev/VolGroup00/LogVol01** is the volume you want to extend by 2 GB):

Procedure 15.1. Extending Swap on an LVM2 Logical Volume

1. Disable swapping for the associated logical volume:

```
# swapoff -v /dev/VolGroup00/LogVol01
```

2. Resize the LVM2 logical volume by 2 GB:

```
# lvresize /dev/VolGroup00/LogVol01 -L +2G
```

3. Format the new swap space:

```
# mkswap /dev/VolGroup00/LogVol01
```

4. Enable the extended logical volume:

```
# swapon -v /dev/VolGroup00/LogVol01
```

To test if the logical volume was successfully extended, use **cat /proc/swaps** or **free** to inspect the swap space.

15.1.2. Creating an LVM2 Logical Volume for Swap

To add a swap volume group (assuming **/dev/VolGroup00/LogVol02** is the swap volume you want to add):

1. Create the LVM2 logical volume of size 2 GB:

```
# lvcreate VolGroup00 -n LogVol02 -L 2G
```

2. Format the new swap space:

```
# mkswap /dev/VolGroup00/LogVol02
```

3. Add the following entry to the **/etc/fstab** file:

```
# /dev/VolGroup00/LogVol02 swap swap defaults 0 0
```

4. Enable the extended logical volume:

```
# swapon -v /dev/VolGroup00/LogVol02
```

To test if the logical volume was successfully created, use **cat /proc/swaps** or **free** to inspect the swap space.

15.1.3. Creating a Swap File

To add a swap file:

Procedure 15.2. Add a swap file

1. Determine the size of the new swap file in megabytes and multiply by 1024 to determine the number of blocks. For example, the block size of a 64 MB swap file is 65536.
2. Type the following command with **count** being equal to the desired block size:

   ```
   # dd if=/dev/zero of=/swapfile bs=1024 count=65536
   ```

3. Setup the swap file with the command:

   ```
   # mkswap /swapfile
   ```

4. It is recommended that the permissions are changed to prevent the swap being world readable.

   ```
   # chmod 0600 /swapfile
   ```

5. To enable the swap file immediately but not automatically at boot time:

   ```
   # swapon /swapfile
   ```

6. To enable it at boot time, edit **/etc/fstab** to include the following entry:

   ```
   /swapfile swap swap defaults 0 0
   ```

   The next time the system boots, it enables the new swap file.

To test if the new swap file was successfully created, use **cat /proc/swaps** or **free** to inspect the swap space.

15.2. Removing Swap Space

Sometimes it can be prudent to reduce swap space after installation. For example, say you downgraded the amount of RAM in your system from 1 GB to 512 MB, but there is 2 GB of swap space still assigned. It might be advantageous to reduce the amount of swap space to 1 GB, since the larger 2 GB could be wasting disk space.

You have three options: remove an entire LVM2 logical volume used for swap, remove a swap file, or reduce swap space on an existing LVM2 logical volume.

15.2.1. Reducing Swap on an LVM2 Logical Volume

To reduce an LVM2 swap logical volume (assuming **/dev/VolGroup00/LogVol01** is the volume you want to reduce):

Procedure 15.3. Reducing an LVM2 swap logical volume

1. Disable swapping for the associated logical volume:

```
# swapoff -v /dev/VolGroup00/LogVol01
```

2. Reduce the LVM2 logical volume by 512 MB:

```
# lvreduce /dev/VolGroup00/LogVol01 -L -512M
```

3. Format the new swap space:

```
# mkswap /dev/VolGroup00/LogVol01
```

4. Enable the extended logical volume:

```
# swapon -v /dev/VolGroup00/LogVol01
```

To test if the swap's logical volume size was successfully reduced, use **cat /proc/swaps** or **free** to inspect the swap space.

15.2.2. Removing an LVM2 Logical Volume for Swap

To remove a swap volume group (assuming **/dev/VolGroup00/LogVol02** is the swap volume you want to remove):

Procedure 15.4. Remove a swap volume group

1. Disable swapping for the associated logical volume:

```
# swapoff -v /dev/VolGroup00/LogVol02
```

2. Remove the LVM2 logical volume of size 512 MB:

```
# lvremove /dev/VolGroup00/LogVol02
```

3. Remove the following entry from the **/etc/fstab** file:

```
/dev/VolGroup00/LogVol02 swap swap defaults 0 0
```

To test if the logical volume size was successfully removed, use **cat /proc/swaps** or **free** to inspect the swap space.

15.2.3. Removing a Swap File

To remove a swap file:

Procedure 15.5. Remove a swap file

1. At a shell prompt, execute the following command to disable the swap file (where **/swapfile** is the swap file):

```
# swapoff -v /swapfile
```

2. Remove its entry from the **/etc/fstab** file.
3. Remove the actual file:

```
# rm /swapfile
```

15.3. Moving Swap Space

To move swap space from one location to another, follow the steps for removing swap space, and then follow the steps for adding swap space.

Chapter 16. Disk Quotas

Disk space can be restricted by implementing disk quotas which alert a system administrator before a user consumes too much disk space or a partition becomes full.

Disk quotas can be configured for individual users as well as user groups. This makes it possible to manage the space allocated for user-specific files (such as email) separately from the space allocated to the projects a user works on (assuming the projects are given their own groups).

In addition, quotas can be set not just to control the number of disk blocks consumed but to control the number of inodes (data structures that contain information about files in UNIX file systems). Because inodes are used to contain file-related information, this allows control over the number of files that can be created.

The **quota** RPM must be installed to implement disk quotas.

16.1. Configuring Disk Quotas

To implement disk quotas, use the following steps:

1. Enable quotas per file system by modifying the **/etc/fstab** file.
2. Remount the file system(s).
3. Create the quota database files and generate the disk usage table.
4. Assign quota policies.

Each of these steps is discussed in detail in the following sections.

16.1.1. Enabling Quotas

As root, using a text editor, edit the **/etc/fstab** file.

Example 16.1. Edit /etc/fstab

For example, to use the text editor **vim** type the following:

```
# vim /etc/fstab
```

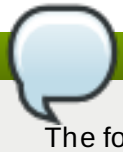
Add the **usrquota** and/or **grpquota** options to the file systems that require quotas:

Example 16.2. Add quotas

```
/dev/VolGroup00/LogVol00 /         ext3    defaults        1 1
LABEL=/boot              /boot     ext3    defaults        1 2
none                     /dev/pts  devpts  gid=5,mode=620  0 0
none                     /dev/shm  tmpfs   defaults        0 0
none                     /proc     proc    defaults        0 0
```

```
none                    /sys        sysfs   defaults        0 0
/dev/VolGroup00/LogVol02 /home      ext3    defaults,usrquota,grpquota
1 2
/dev/VolGroup00/LogVol01 swap       swap    defaults        0 0 . . .
```

In this example, the **/home** file system has both user and group quotas enabled.



Note

The following examples assume that a separate **/home** partition was created during the installation of Red Hat Enterprise Linux. The root (**/**) partition can be used for setting quota policies in the **/etc/fstab** file.

16.1.2. Remounting the File Systems

After adding the **usrquota** and/or **grpquota** options, remount each file system whose **fstab** entry has been modified. If the file system is not in use by any process, use one of the following methods:

- Issue the **umount** command followed by the **mount** command to remount the file system. Refer to the **man** page for both **umount** and **mount** for the specific syntax for mounting and unmounting various file system types.
- Issue the **mount -o remount *file-system*** command (where ***file-system***** is the name of the file system) to remount the file system. For example, to remount the **/home** file system, the command to issue is **mount -o remount /home**.

If the file system is currently in use, the easiest method for remounting the file system is to reboot the system.

16.1.3. Creating the Quota Database Files

After each quota-enabled file system is remounted run the **quotacheck** command.

The **quotacheck** command examines quota-enabled file systems and builds a table of the current disk usage per file system. The table is then used to update the operating system's copy of disk usage. In addition, the file system's disk quota files are updated.

To create the quota files (**aquota.user** and **aquota.group**) on the file system, use the **-c** option of the **quotacheck** command.

Example 16.3. Create quota files

For example, if user and group quotas are enabled for the **/home** file system, create the files in the **/home** directory:

```
# quotacheck -cug /home
```

The **-c** option specifies that the quota files should be created for each file system with quotas enabled, the **-u** option specifies to check for user quotas, and the **-g** option specifies to check for group quotas.

If neither the **-u** or **-g** options are specified, only the user quota file is created. If only **-g** is specified, only the group quota file is created.

After the files are created, run the following command to generate the table of current disk usage per file system with quotas enabled:

```
# quotacheck -avug
```

The options used are as follows:

a

Check all quota-enabled, locally-mounted file systems

v

Display verbose status information as the quota check proceeds

u

Check user disk quota information

g

Check group disk quota information

After **quotacheck** has finished running, the quota files corresponding to the enabled quotas (user and/or group) are populated with data for each quota-enabled locally-mounted file system such as **/home**.

16.1.4. Assigning Quotas per User

The last step is assigning the disk quotas with the **edquota** command.

To configure the quota for a user, as root in a shell prompt, execute the command:

```
# edquota username
```

Perform this step for each user who needs a quota. For example, if a quota is enabled in **/etc/fstab** for the **/home** partition (**/dev/VolGroup00/LogVol02** in the example below) and the command **edquota testuser** is executed, the following is shown in the editor configured as the default for the system:

```
Disk quotas for user testuser (uid 501):
Filesystem                   blocks     soft     hard    inodes   soft
hard
/dev/VolGroup00/LogVol02  440436        0        0     37418      0
0
```

Note

The text editor defined by the **EDITOR** environment variable is used by **edquota**. To change the editor, set the **EDITOR** environment variable in your **~/.bash_profile** file to the full path of the editor of your choice.

The first column is the name of the file system that has a quota enabled for it. The second column shows how many blocks the user is currently using. The next two columns are used to set soft and hard block limits for the user on the file system. The **inodes** column shows how many inodes the user is currently using. The last two columns are used to set the soft and hard inode limits for the user on the file system.

The hard block limit is the absolute maximum amount of disk space that a user or group can use. Once this limit is reached, no further disk space can be used.

The soft block limit defines the maximum amount of disk space that can be used. However, unlike the hard limit, the soft limit can be exceeded for a certain amount of time. That time is known as the *grace period*. The grace period can be expressed in seconds, minutes, hours, days, weeks, or months.

If any of the values are set to 0, that limit is not set. In the text editor, change the desired limits.

Example 16.4. Change desired limits

For example:

```
Disk quotas for user testuser (uid 501):
Filesystem                blocks     soft     hard   inodes   soft
hard
/dev/VolGroup00/LogVol02  440436   500000   550000    37418      0
0
```

To verify that the quota for the user has been set, use the command:

```
# quota username
Disk quotas for user username (uid 501):
   Filesystem  blocks   quota   limit   grace   files   quota   limit
grace
     /dev/sdb    1000*   1000    1000               0       0       0
```

16.1.5. Assigning Quotas per Group

Quotas can also be assigned on a per-group basis. For example, to set a group quota for the **devel** group (the group must exist prior to setting the group quota), use the command:

```
# edquota -g devel
```

This command displays the existing quota for the group in the text editor:

```
Disk quotas for group devel (gid 505):
Filesystem                blocks    soft     hard    inodes    soft
hard
/dev/VolGroup00/LogVol02  440400       0        0     37418       0
0
```

Modify the limits, then save the file.

To verify that the group quota has been set, use the command:

```
# quota -g devel
```

16.1.6. Setting the Grace Period for Soft Limits

If a given quota has soft limits, you can edit the grace period (i.e. the amount of time a soft limit can be exceeded) with the following command:

```
# edquota -t
```

This command works on quotas for inodes or blocks, for either users or groups.

Important

While other **edquota** commands operate on quotas for a particular user or group, the **-t** option operates on every file system with quotas enabled.

16.2. Managing Disk Quotas

If quotas are implemented, they need some maintenance — mostly in the form of watching to see if the quotas are exceeded and making sure the quotas are accurate.

Of course, if users repeatedly exceed their quotas or consistently reach their soft limits, a system administrator has a few choices to make depending on what type of users they are and how much disk space impacts their work. The administrator can either help the user determine how to use less disk space or increase the user's disk quota.

16.2.1. Enabling and Disabling

It is possible to disable quotas without setting them to 0. To turn all user and group quotas off, use the following command:

```
# quotaoff -vaug
```

If neither the **-u** or **-g** options are specified, only the user quotas are disabled. If only **-g** is specified, only group quotas are disabled. The **-v** switch causes verbose status information to display as the command executes.

To enable quotas again, use the **quotaon** command with the same options.

For example, to enable user and group quotas for all file systems, use the following command:

```
# quotaon -vaug
```

To enable quotas for a specific file system, such as **/home**, use the following command:

```
# quotaon -vug /home
```

If neither the **-u** or **-g** options are specified, only the user quotas are enabled. If only **-g** is specified, only group quotas are enabled.

16.2.2. Reporting on Disk Quotas

Creating a disk usage report entails running the **repquota** utility.

Example 16.5. Output of repquota command

For example, the command **repquota /home** produces this output:

```
*** Report for user quotas on device /dev/mapper/VolGroup00-LogVol02
Block grace time: 7days; Inode grace time: 7days
   Block limits   File limits
User  used soft hard grace used soft hard grace
----------------------------------------------------------------------
root      --      36       0       0              4     0     0
kristin   --     540       0       0            125     0     0
testuser  --  440400  500000  550000          37418     0     0
```

To view the disk usage report for all (option **-a**) quota-enabled file systems, use the command:

```
# repquota -a
```

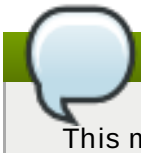
While the report is easy to read, a few points should be explained. The **--** displayed after each user is a quick way to determine whether the block or inode limits have been exceeded. If either soft limit is exceeded, a **+** appears in place of the corresponding **-**; the first **-** represents the block limit, and the second represents the inode limit.

The **grace** columns are normally blank. If a soft limit has been exceeded, the column contains a time specification equal to the amount of time remaining on the grace period. If the grace period has expired, **none** appears in its place.

16.2.3. Keeping Quotas Accurate

When a file system fails to unmount cleanly (due to a system crash, for example), it is necessary to run **quotacheck**. However, **quotacheck** can be run on a regular basis, even if the system has not crashed. Safe methods for periodically running **quotacheck** include:

Ensuring quotacheck runs on next reboot



Note: Best method for most systems

This method works best for (busy) multiuser systems which are periodically rebooted.

As root, place a shell script into the **/etc/cron.daily/** or **/etc/cron.weekly/** directory—or schedule one using the **crontab -e** command—that contains the **touch /forcequotacheck** command. This creates an empty **forcequotacheck** file in the root directory, which the system init script looks for at boot time. If it is found, the init script runs **quotacheck**. Afterward, the init script removes the **/forcequotacheck** file; thus, scheduling this file to be created periodically with **cron** ensures that **quotacheck** is run during the next reboot.

For more information about **cron**, refer to **man cron**.

Running quotacheck in single user mode

An alternative way to safely run **quotacheck** is to boot the system into single-user mode to

An alternative way to safely run **quotacheck** is to boot the system into single-user mode to prevent the possibility of data corruption in quota files and run the following commands:

```
# quotaoff -vaug /file_system
```

```
# quotacheck -vaug /file_system
```

```
# quotaon -vaug /file_system
```

Running quotacheck on a running system

If necessary, it is possible to run **quotacheck** on a machine during a time when no users are logged in, and thus have no open files on the file system being checked. Run the command **quotacheck -vaug *file_system*** ; this command will fail if **quotacheck** cannot remount the given *file_system* as read-only. Note that, following the check, the file system will be remounted read-write.

Warning

Running **quotacheck** on a live file system mounted read-write is not recommended due to the possibility of quota file corruption.

Refer to **man cron** for more information about configuring **cron**.

16.3. Disk Quota References

For more information on disk quotas, refer to the **man** pages of the following commands:

- **quotacheck**
- **edquota**
- **repquota**
- **quota**
- **quotaon**
- **quotaoff**

Chapter 17. Redundant Array of Independent Disks (RAID)

The basic idea behind RAID is to combine multiple small, inexpensive disk drives into an array to accomplish performance or redundancy goals not attainable with one large and expensive drive. This array of drives appears to the computer as a single logical storage unit or drive.

RAID allows information to be spread across several disks. RAID uses techniques such as *disk striping* (RAID Level 0), *disk mirroring* (RAID Level 1), and *disk striping with parity* (RAID Level 5) to achieve redundancy, lower latency, increased bandwidth, and maximized ability to recover from hard disk crashes.

RAID distributes data across each drive in the array by breaking it down into consistently-sized chunks (commonly 256K or 512k, although other values are acceptable). Each chunk is then written to a hard drive in the RAID array according to the RAID level employed. When the data is read, the process is reversed, giving the illusion that the multiple drives in the array are actually one large drive.

System Administrators and others who manage large amounts of data would benefit from using RAID technology. Primary reasons to deploy RAID include:

- Enhances speed
- Increases storage capacity using a single virtual disk
- Minimizes data loss from disk failure

17.1. RAID Types

There are three possible RAID approaches: Firmware RAID, Hardware RAID and Software RAID.

Firmware RAID

Firmware RAID (also known as ATARAID) is a type of software RAID where the RAID sets can be configured using a firmware-based menu. The firmware used by this type of RAID also hooks into the BIOS, allowing you to boot from its RAID sets. Different vendors use different on-disk metadata formats to mark the RAID set members. The Intel Matrix RAID is a good example of a firmware RAID system.

Hardware RAID

The hardware-based array manages the RAID subsystem independently from the host. It presents a single disk per RAID array to the host.

A Hardware RAID device may be internal or external to the system, with internal devices commonly consisting of a specialized controller card that handles the RAID tasks transparently to the operating system and with external devices commonly connecting to the system via SCSI, fiber channel, iSCSI, InfiniBand, or other high speed network interconnect and presenting logical volumes to the system.

RAID controller cards function like a SCSI controller to the operating system, and handle all the actual drive communications. The user plugs the drives into the RAID controller (just like a normal SCSI controller) and then adds them to the RAID controllers configuration. The operating system will not be able to tell the difference.

Software RAID

Software RAID implements the various RAID levels in the kernel disk (block device) code. It offers the cheapest possible solution, as expensive disk controller cards or hot-swap chassis [4] are not required. Software RAID also works with cheaper IDE disks as well as SCSI disks. With today's faster CPUs, Software RAID also generally outperforms Hardware RAID.

The Linux kernel contains a *multi-disk* (MD) driver that allows the RAID solution to be completely hardware independent. The performance of a software-based array depends on the server CPU performance and load.

Here are some of the key features of the Linux software RAID stack:

- Multi-threaded design
- Portability of arrays between Linux machines without reconstruction
- Backgrounded array reconstruction using idle system resources
- Hot-swappable drive support
- Automatic CPU detection to take advantage of certain CPU features such as streaming SIMD support
- Automatic correction of bad sectors on disks in an array
- Regular consistency checks of RAID data to ensure the health of the array
- Proactive monitoring of arrays with email alerts sent to a designated email address on important events
- Write-intent bitmaps which drastically increase the speed of resync events by allowing the kernel to know precisely which portions of a disk need to be resynced instead of having to resync the entire array
- Resync checkpointing so that if you reboot your computer during a resync, at startup the resync will pick up where it left off and not start all over again
- The ability to change parameters of the array after installation. For example, you can grow a 4-disk RAID5 array to a 5-disk RAID5 array when you have a new disk to add. This grow operation is done live and does not require you to reinstall on the new array.

17.2. RAID Levels and Linear Support

RAID supports various configurations, including levels 0, 1, 4, 5, 6, 10, and linear. These RAID types are defined as follows:

Level 0

RAID level 0, often called "striping," is a performance-oriented striped data mapping technique. This means the data being written to the array is broken down into strips and written across the member disks of the array, allowing high I/O performance at low inherent cost but provides no redundancy.

Many RAID level 0 implementations will only stripe the data across the member devices up to the size of the smallest device in the array. This means that if you have multiple devices with slightly different sizes, each device will get treated as though it is the same size as the smallest drive. Therefore, the common storage capacity of a level 0 array is equal to the

capacity of the smallest member disk in a Hardware RAID or the capacity of smallest member partition in a Software RAID multiplied by the number of disks or partitions in the array.

Level 1

RAID level 1, or "mirroring," has been used longer than any other form of RAID. Level 1 provides redundancy by writing identical data to each member disk of the array, leaving a "mirrored" copy on each disk. Mirroring remains popular due to its simplicity and high level of data availability. Level 1 operates with two or more disks, and provides very good data reliability and improves performance for read-intensive applications but at a relatively high cost. [5]

The storage capacity of the level 1 array is equal to the capacity of the smallest mirrored hard disk in a Hardware RAID or the smallest mirrored partition in a Software RAID. Level 1 redundancy is the highest possible among all RAID types, with the array being able to operate with only a single disk present.

Level 4

Level 4 uses parity [6] concentrated on a single disk drive to protect data. Because the dedicated parity disk represents an inherent bottleneck on all write transactions to the RAID array, level 4 is seldom used without accompanying technologies such as write-back caching, or in specific circumstances where the system administrator is intentionally designing the software RAID device with this bottleneck in mind (such as an array that will have little to no write transactions once the array is populated with data). RAID level 4 is so rarely used that it is not available as an option in Anaconda. However, it could be created manually by the user if truly needed.

The storage capacity of Hardware RAID level 4 is equal to the capacity of the smallest member partition multiplied by the number of partitions *minus one*. Performance of a RAID level 4 array will always be asymmetrical, meaning reads will outperform writes. This is because writes consume extra CPU and main memory bandwidth when generating parity, and then also consume extra bus bandwidth when writing the actual data to disks because you are writing not only the data, but also the parity. Reads need only read the data and not the parity unless the array is in a degraded state. As a result, reads generate less traffic to the drives and across the busses of the computer for the same amount of data transfer under normal operating conditions.

Level 5

This is the most common type of RAID. By distributing parity across all of an array's member disk drives, RAID level 5 eliminates the write bottleneck inherent in level 4. The only performance bottleneck is the parity calculation process itself. With modern CPUs and Software RAID, that is usually not a bottleneck at all since modern CPUs can generate parity very fast. However, if you have a sufficiently large number of member devices in a software RAID5 array such that the combined aggregate data transfer speed across all devices is high enough, then this bottleneck can start to come into play.

As with level 4, level 5 has asymmetrical performance, with reads substantially outperforming writes. The storage capacity of RAID level 5 is calculated the same way as with level 4.

Level 6

This is a common level of RAID when data redundancy and preservation, and not performance, are the paramount concerns, but where the space inefficiency of level 1 is not acceptable. Level 6 uses a complex parity scheme to be able to recover from the loss of any

two drives in the array. This complex parity scheme creates a significantly higher CPU burden on software RAID devices and also imposes an increased burden during write transactions. As such, level 6 is considerably more asymmetrical in performance than levels 4 and 5.

The total capacity of a RAID level 6 array is calculated similarly to RAID level 5 and 4, except that you must subtract 2 devices (instead of 1) from the device count for the extra parity storage space.

Level 10

This RAID level attempts to combine the performance advantages of level 0 with the redundancy of level 1. It also helps to alleviate some of the space wasted in level 1 arrays with more than 2 devices. With level 10, it is possible to create a 3-drive array configured to store only 2 copies of each piece of data, which then allows the overall array size to be 1.5 times the size of the smallest devices instead of only equal to the smallest device (like it would be with a 3-device, level 1 array).

The number of options available when creating level 10 arrays (as well as the complexity of selecting the right options for a specific use case) make it impractical to create during installation. It is possible to create one manually using the command line **mdadm** tool. For details on the options and their respective performance trade-offs, refer to **man md**.

Linear RAID

Linear RAID is a simple grouping of drives to create a larger virtual drive. In linear RAID, the chunks are allocated sequentially from one member drive, going to the next drive only when the first is completely filled. This grouping provides no performance benefit, as it is unlikely that any I/O operations will be split between member drives. Linear RAID also offers no redundancy and, in fact, decreases reliability — if any one member drive fails, the entire array cannot be used. The capacity is the total of all member disks.

17.3. Linux RAID Subsystems

RAID in Linux is composed of the following subsystems:

Linux Hardware RAID controller drivers

Hardware RAID controllers have no specific RAID subsystem in Linux. Because they use special RAID chipsets, hardware RAID controllers come with their own drivers; these drivers allow the system to detect the RAID sets as regular disks.

mdraid

The **mdraid** subsystem was designed as a software RAID solution for Linux; it is also the preferred solution for software RAID under Linux. This subsystem uses its own metadata format, generally referred to as native **mdraid** metadata.

mdraid also supports other metadata formats, known as external metadata. Red Hat Enterprise Linux 6 uses **mdraid** with external metadata to access ISW / IMSM (Intel firmware RAID) sets. **mdraid** sets are configured and controlled through the **mdadm** utility.

dmraid

Device-mapper RAID or **dmraid** refers to device-mapper kernel code that offers the mechanism to piece disks together into a RAID set. This same kernel code does not provide any RAID configuration mechanism.

dmraid is configured entirely in user-space, making it easy to support various on-disk metadata formats. As such, **dmraid** is used on a wide variety of firmware RAID implementations. **dmraid** also supports Intel firmware RAID, although Red Hat Enterprise Linux 6 uses **mdraid** to access Intel firmware RAID sets.

17.4. RAID Support in the Installer

The **Anaconda** installer will automatically detect any hardware and firmware RAID sets on a system, making them available for installation. **Anaconda** also supports software RAID using **mdraid**, and can recognize existing **mdraid** sets.

Anaconda provides utilities for creating RAID sets during installation; however, these utilities only allow partitions (as opposed to entire disks) to be members of new sets. To use an entire disk for a set, simply create a partition on it spanning the entire disk, and use that partition as the RAID set member.

When the root file system uses a RAID set, **Anaconda** will add special kernel command-line options to the bootloader configuration telling the **initrd** which RAID set(s) to activate before searching for the root file system.

For instructions on configuring RAID during installation, refer to the Red Hat Enterprise Linux 6 *Installation Guide*.

17.5. Configuring RAID Sets

Most RAID sets are configured during creation, typically through the firmware menu or from the installer. In some cases, you may need to create or modify RAID sets after installing the system, preferably without having to reboot the machine and enter the firmware menu to do so.

Some hardware RAID controllers allow you to configure RAID sets on-the-fly or even define completely new sets after adding extra disks. This requires the use of driver-specific utilities, as there is no standard API for this. Refer to your hardware RAID controller's driver documentation for information on this.

mdadm

The **mdadm** command-line tool is used to manage software RAID in Linux, i.e. **mdraid**. For information on the different **mdadm** modes and options, refer to **man mdadm**. The **man** page also contains useful examples for common operations like creating, monitoring, and assembling software RAID arrays.

dmraid

As the name suggests, **dmraid** is used to manage device-mapper RAID sets. The **dmraid** tool finds ATARAID devices using multiple metadata format handlers, each supporting various formats. For a complete list of supported formats, run **dmraid -l**.

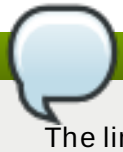
As mentioned earlier in Section 17.3, “Linux RAID Subsystems”, the **dmraid** tool cannot configure RAID sets after creation. For more information about using **dmraid**, refer to **man dmraid**.

17.6. Advanced RAID Device Creation

In some cases, you may wish to install the operating system on an array that can't be created after the installation completes. Usually, this means setting up the **/boot** or root file system arrays on a complex RAID device; in such cases, you may need to use array options that are not supported by **Anaconda**. To work around this, perform the following procedure:

Procedure 17.1. Advanced RAID device creation

1. Insert the install disk as you normally would.
2. During the initial boot up, select **Rescue Mode** instead of **Install** or **Upgrade**. When the system fully boots into *Rescue mode*, the user will be presented with a command line terminal.
3. From this terminal, use **parted** to create RAID partitions on the target hard drives. Then, use **mdadm** to manually create raid arrays from those partitions using any and all settings and options available. For more information on how to do these, refer to Chapter 13, *Partitions*, **man parted**, and **man mdadm**.
4. Once the arrays are created, you can optionally create file systems on the arrays as well. Refer to Section 11.2, “Overview of Supported File Systems” for basic technical information on file systems supported by Red Hat Enterprise Linux 6.
5. Reboot the computer and this time select **Install** or **Upgrade** to install as normal. As **Anaconda** searches the disks in the system, it will find the pre-existing RAID devices.
6. When asked about how to use the disks in the system, select **Custom Layout** and click **Next**. In the device listing, the pre-existing MD RAID devices will be listed.
7. Select a RAID device, click **Edit** and configure its mount point and (optionally) the type of file system it should use (if you did not create one earlier) then click **Done**. **Anaconda** will perform the install to this pre-existing RAID device, preserving the custom options you selected when you created it in *Rescue Mode*.



Note

The limited *Rescue Mode* of the installer does not include **man** pages. Both the **man mdadm** and **man md** contain useful information for creating custom RAID arrays, and may be needed throughout the workaround. As such, it can be helpful to either have access to a machine with these **man** pages present, or to print them out prior to booting into *Rescue Mode* and creating your custom arrays.

[4] A hot-swap chassis allows you to remove a hard drive without having to power-down your system.

[5] RAID level 1 comes at a high cost because you write the same information to all of the disks in the array, provides data reliability, but in a much less space-efficient manner than parity based RAID levels such as level 5. However, this space inefficiency comes with a performance benefit: parity-based RAID levels consume considerably more CPU power in order to generate the parity while RAID level 1 simply writes the same data more than once to the multiple RAID members with very little CPU overhead. As such, RAID level 1 can outperform the parity-based RAID levels on machines where software RAID is employed and CPU resources on the machine are consistently taxed with operations other than RAID activities.

[6] Parity information is calculated based on the contents of the rest of the member disks in the array. This information can then be used to reconstruct data when one disk in the array fails. The reconstructed data can then be used to satisfy I/O requests to the failed disk before it is replaced and to repopulate the failed disk after it has been replaced.

Chapter 18. Using the `mount` Command

On Linux, UNIX, and similar operating systems, file systems on different partitions and removable devices (CDs, DVDs, or USB flash drives for example) can be attached to a certain point (the *mount point*) in the directory tree, and then detached again. To attach or detach a file system, use the **mount** or **umount** command respectively. This chapter describes the basic use of these commands, as well as some advanced topics, such as moving a mount point or creating shared subtrees.

18.1. Listing Currently Mounted File Systems

To display all currently attached file systems, run the **mount** command with no additional arguments:

```
mount
```

This command displays the list of known mount points. Each line provides important information about the device name, the file system type, the directory in which it is mounted, and relevant mount options in the following form:

device on *directory* type *type* (*options*)

The **findmnt** utility, which allows users to list mounted file systems in a tree-like form, is also available from Red Hat Enterprise Linux 6.1. To display all currently attached file systems, run the **findmnt** command with no additional arguments:

```
findmnt
```

18.1.1. Specifying the File System Type

By default, the output of the **mount** command includes various virtual file systems such as **sysfs** and **tmpfs**. To display only the devices with a certain file system type, supply the **-t** option on the command line:

```
mount -t type
```

Similarly, to display only the devices with a certain file system type by using the **findmnt** command, type:

```
findmnt -t type
```

For a list of common file system types, refer to Table 18.1, “Common File System Types”. For an example usage, see Example 18.1, “Listing Currently Mounted **ext4** File Systems”.

Example 18.1. Listing Currently Mounted ext4 File Systems

Usually, both **/** and **/boot** partitions are formatted to use **ext4**. To display only the mount points that use this file system, type the following at a shell prompt:

```
~]$ mount -t ext4
/dev/sda2 on / type ext4 (rw)
/dev/sda1 on /boot type ext4 (rw)
```

To list such mount points using the **findmnt** command, type:

```
~]$ findmnt -t ext4
TARGET SOURCE    FSTYPE OPTIONS
/      /dev/sda2 ext4   rw,realtime,seclabel,barrier=1,data=ordered
/boot  /dev/sda1 ext4   rw,realtime,seclabel,barrier=1,data=ordered
```

18.2. Mounting a File System

To attach a certain file system, use the **mount** command in the following form:

```
mount [option…] device directory
```

The *device* can be identified by a full path to a *block device* (for example, “/dev/sda3”), a *universally unique identifier* (UUID; for example, “UUID=34795a28-ca6d-4fd8-a347-73671d0c19cb”), or a *volume label* (for example, “LABEL=home”). Note that while a file system is mounted, the original content of the *directory* is not accessible.

Important: Make Sure the Directory is Not in Use

Linux does not prevent a user from mounting a file system to a directory with a file system already attached to it. To determine whether a particular directory serves as a mount point, run the **findmnt** utility with the directory as its argument and verify the exit code:

```
findmnt directory; echo $?
```

If no file system is attached to the directory, the above command returns **1**.

When the **mount** command is run without all required information (that is, without the device name, the target directory, or the file system type), it reads the content of the **/etc/fstab** configuration file to see if the given file system is listed. This file contains a list of device names and the directories in which the selected file systems should be mounted, as well as the file system type and mount options. Because of this, when mounting a file system that is specified in this file, you can use one of the following variants of the command:

```
mount [option…] directory
mount [option…] device
```

Note that permissions are required to mount the file systems unless the command is run as **root** (see Section 18.2.2, “Specifying the Mount Options”).

Note: Determining the UUID and Label of a Particular Device

To determine the UUID and—if the device uses it—the label of a particular device, use the **blkid** command in the following form:

```
blkid device
```

For example, to display information about **/dev/sda3**, type:

```
~]# blkid /dev/sda3
/dev/sda3: LABEL="home" UUID="34795a28-ca6d-4fd8-a347-73671d0c19cb"
TYPE="ext3"
```

18.2.1. Specifying the File System Type

In most cases, **mount** detects the file system automatically. However, there are certain file systems, such as **NFS** (Network File System) or **CIFS** (Common Internet File System), that are not recognized, and need to be specified manually. To specify the file system type, use the **mount** command in the following form:

```
mount -t type device directory
```

Table 18.1, “Common File System Types” provides a list of common file system types that can be used with the **mount** command. For a complete list of all available file system types, consult the relevant manual page as referred to in Section 18.4.1, “Manual Page Documentation”.

Table 18.1. Common File System Types

Type	Description
ext2	The **ext2** file system.
ext3	The **ext3** file system.
ext4	The **ext4** file system.
iso9660	The **ISO 9660** file system. It is commonly used by optical media, typically CDs.
jfs	The **JFS** file system created by IBM.
nfs	The **NFS** file system. It is commonly used to access files over the network.
nfs4	The **NFSv4** file system. It is commonly used to access files over the network.
ntfs	The **NTFS** file system. It is commonly used on machines that are running the Windows operating system.
udf	The **UDF** file system. It is commonly used by optical media, typically DVDs.
vfat	The **FAT** file system. It is commonly used on machines that are running the Windows operating system, and on certain digital media such as USB flash drives or floppy disks.

See Example 18.2, “Mounting a USB Flash Drive” for an example usage.

Example 18.2. Mounting a USB Flash Drive

Older USB flash drives often use the FAT file system. Assuming that such drive uses the **/dev/sdc1** device and that the **/media/flashdisk/** directory exists, mount it to this directory by typing the following at a shell prompt as **root**:

```
~]# mount -t vfat /dev/sdc1 /media/flashdisk
```

18.2.2. Specifying the Mount Options

To specify additional mount options, use the command in the following form:

```
mount -o options device directory
```

When supplying multiple options, do not insert a space after a comma, or **mount** will incorrectly interpret the values following spaces as additional parameters.

Table 18.2, “Common Mount Options” provides a list of common mount options. For a complete list of all available options, consult the relevant manual page as referred to in Section 18.4.1, “Manual Page Documentation”.

Table 18.2. Common Mount Options

Option	Description
async	Allows the asynchronous input/output operations on the file system.
auto	Allows the file system to be mounted automatically using the **mount -a** command.
defaults	Provides an alias for **async,auto,dev,exec,nouser,rw,suid**.
exec	Allows the execution of binary files on the particular file system.
loop	Mounts an image as a loop device.
noauto	Default behavior disallows the automatic mount of the file system using the **mount -a** command.
noexec	Disallows the execution of binary files on the particular file system.
nouser	Disallows an ordinary user (that is, other than **root**) to mount and unmount the file system.
remount	Remounts the file system in case it is already mounted.
ro	Mounts the file system for reading only.
rw	Mounts the file system for both reading and writing.
user	Allows an ordinary user (that is, other than **root**) to mount and unmount the file system.

See Example 18.3, “Mounting an ISO Image” for an example usage.

Example 18.3. Mounting an ISO Image

An ISO image (or a disk image in general) can be mounted by using the loop device. Assuming that the ISO image of the Fedora 14 installation disc is present in the current working directory and that the **/media/cdrom/** directory exists, mount the image to this directory by running the following command as **root**:

```
~]# mount -o ro,loop Fedora-14-x86_64-Live-Desktop.iso /media/cdrom
```

Note that ISO 9660 is by design a read-only file system.

18.2.3. Sharing Mounts

Occasionally, certain system administration tasks require access to the same file system from more than one place in the directory tree (for example, when preparing a chroot environment). This is possible, and Linux allows you to mount the same file system to as many directories as necessary. Additionally, the **mount** command implements the **--bind** option that provides a means for duplicating certain mounts. Its usage is as follows:

```
mount --bind old_directory new_directory
```

Although this command allows a user to access the file system from both places, it does not apply on the file systems that are mounted within the original directory. To include these mounts as well, type:

```
mount --rbind old_directory new_directory
```

Additionally, to provide as much flexibility as possible, Red Hat Enterprise Linux 6 implements the functionality known as *shared subtrees*. This feature allows the use of the following four mount types:

Shared Mount

A shared mount allows the creation of an exact replica of a given mount point. When a mount point is marked as a shared mount, any mount within the original mount point is reflected in it, and vice versa. To change the type of a mount point to a shared mount, type the following at a shell prompt:

```
mount --make-shared mount_point
```

Alternatively, to change the mount type for the selected mount point and all mount points under it, type:

```
mount --make-rshared mount_point
```

See Example 18.4, “Creating a Shared Mount Point” for an example usage.

Example 18.4. Creating a Shared Mount Point

There are two places where other file systems are commonly mounted: the **/media** directory for removable media, and the **/mnt** directory for temporarily mounted file systems. By using a shared mount, you can make these two directories share the same content. To do so, as **root**, mark the **/media** directory as “shared”:

```
~]# mount --bind /media /media
~]# mount --make-shared /media
```

Then create its duplicate in **/mnt** by using the following command:

```
~]# mount --bind /media /mnt
```

It is now possible to verify that a mount within **/media** also appears in **/mnt**. For example, if the CD-ROM drive contains non-empty media and the **/media/cdrom/** directory exists, run the following commands:

```
~]# mount /dev/cdrom /media/cdrom
~]# ls /media/cdrom
EFI  GPL  isolinux  LiveOS
~]# ls /mnt/cdrom
EFI  GPL  isolinux  LiveOS
```

Similarly, it is possible to verify that any file system mounted in the **/mnt** directory is reflected in **/media**. For instance, if a non-empty USB flash drive that uses the **/dev/sdc1** device is plugged in and the **/mnt/flashdisk/** directory is present, type:

```
~]# mount /dev/sdc1 /mnt/flashdisk
~]# ls /media/flashdisk
en-US  publican.cfg
~]# ls /mnt/flashdisk
en-US  publican.cfg
```

Slave Mount

A slave mount allows the creation of a limited duplicate of a given mount point. When a mount point is marked as a slave mount, any mount within the original mount point is reflected in it, but no mount within a slave mount is reflected in its original. To change the type of a mount point to a slave mount, type the following at a shell prompt:

```
mount --make-slave mount_point
```

Alternatively, it is possible to change the mount type for the selected mount point and all mount points under it by typing:

```
mount --make-rslave mount_point
```

See Example 18.5, “Creating a Slave Mount Point” for an example usage.

Example 18.5. Creating a Slave Mount Point

This example shows how to get the content of the **/media** directory to appear in **/mnt** as well, but without any mounts in the **/mnt** directory to be reflected in **/media**. As **root**, first mark the **/media** directory as “shared”:

```
~]# mount --bind /media /media
~]# mount --make-shared /media
```

Then create its duplicate in **/mnt**, but mark it as “slave”:

```
~]# mount --bind /media /mnt
~]# mount --make-slave /mnt
```

Now verify that a mount within **/media** also appears in **/mnt**. For example, if the CD-ROM drive contains non-empty media and the **/media/cdrom/** directory exists, run the following commands:

```
~]# mount /dev/cdrom /media/cdrom
~]# ls /media/cdrom
EFI  GPL  isolinux  LiveOS
```

```
~]# ls /mnt/cdrom
EFI  GPL  isolinux  LiveOS
```

Also verify that file systems mounted in the **/mnt** directory are not reflected in **/media**. For instance, if a non-empty USB flash drive that uses the **/dev/sdc1** device is plugged in and the **/mnt/flashdisk/** directory is present, type:

```
~]# mount /dev/sdc1 /mnt/flashdisk
~]# ls /media/flashdisk
~]# ls /mnt/flashdisk
en-US  publican.cfg
```

Private Mount

A private mount is the default type of mount, and unlike a shared or slave mount, it does not receive or forward any propagation events. To explicitly mark a mount point as a private mount, type the following at a shell prompt:

```
mount --make-private mount_point
```

Alternatively, it is possible to change the mount type for the selected mount point and all mount points under it:

```
mount --make-rprivate mount_point
```

See Example 18.6, “Creating a Private Mount Point” for an example usage.

Example 18.6. Creating a Private Mount Point

Taking into account the scenario in Example 18.4, “Creating a Shared Mount Point”, assume that a shared mount point has been previously created by using the following commands as **root**:

```
~]# mount --bind /media /media
~]# mount --make-shared /media
~]# mount --bind /media /mnt
```

To mark the **/mnt** directory as “private”, type:

```
~]# mount --make-private /mnt
```

It is now possible to verify that none of the mounts within **/media** appears in **/mnt**. For example, if the CD-ROM drives contains non-empty media and the **/media/cdrom/** directory exists, run the following commands:

```
~]# mount /dev/cdrom /media/cdrom
~]# ls /media/cdrom
EFI  GPL  isolinux  LiveOS
~]# ls /mnt/cdrom
~]#
```

It is also possible to verify that file systems mounted in the **/mnt** directory are not reflected in **/media**. For instance, if a non-empty USB flash drive that uses the **/dev/sdc1** device is plugged in and the **/mnt/flashdisk/** directory is present, type:

```
~]# mount /dev/sdc1 /mnt/flashdisk
~]# ls /media/flashdisk
~]# ls /mnt/flashdisk
en-US  publican.cfg
```

Unbindable Mount

In order to prevent a given mount point from being duplicated whatsoever, an unbindable mount is used. To change the type of a mount point to an unbindable mount, type the following at a shell prompt:

```
mount --make-unbindable mount_point
```

Alternatively, it is possible to change the mount type for the selected mount point and all mount points under it:

```
mount --make-runbindable mount_point
```

See Example 18.7, “Creating an Unbindable Mount Point” for an example usage.

Example 18.7. Creating an Unbindable Mount Point

To prevent the **/media** directory from being shared, as **root**, type the following at a shell prompt:

```
~]# mount --bind /media /media
~]# mount --make-unbindable /media
```

This way, any subsequent attempt to make a duplicate of this mount will fail with an error:

```
~]# mount --bind /media /mnt
mount: wrong fs type, bad option, bad superblock on /media,
missing codepage or helper program, or other error
In some cases useful info is found in syslog - try
dmesg | tail  or so
```

18.2.4. Moving a Mount Point

To change the directory in which a file system is mounted, use the following command:

```
mount --move old_directory new_directory
```

See Example 18.8, “Moving an Existing NFS Mount Point” for an example usage.

Example 18.8. Moving an Existing NFS Mount Point

An NFS storage contains user directories and is already mounted in **/mnt/userdirs/**. As **root**, move this mount point to **/home** by using the following command:

```
~]# mount --move /mnt/userdirs /home
```

To verify the mount point has been moved, list the content of both directories:

```
~]# ls /mnt/userdirs
~]# ls /home
jill  joe
```

18.3. Unmounting a File System

To detach a previously mounted file system, use either of the following variants of the **umount** command:

```
umount directory
umount device
```

Note that unless this is performed while logged in as **root**, the correct permissions must be available to unmount the file system (see Section 18.2.2, "Specifying the Mount Options"). See Example 18.9, "Unmounting a CD" for an example usage.

Important: Make Sure the Directory is Not in Use

When a file system is in use (for example, when a process is reading a file on this file system, or when it is used by the kernel), running the **umount** command will fail with an error. To determine which processes are accessing the file system, use the **fuser** command in the following form:

```
fuser -m directory
```

For example, to list the processes that are accessing a file system mounted to the **/media/cdrom/** directory, type:

```
~]$ fuser -m /media/cdrom
/media/cdrom:         1793  2013  2022  2435 10532c 10672c
```

Example 18.9. Unmounting a CD

To unmount a CD that was previously mounted to the **/media/cdrom/** directory, type the following at a shell prompt:

```
~]$ umount /media/cdrom
```

18.4. mount Command References

The following resources provide an in-depth documentation on the subject.

18.4.1. Manual Page Documentation

- **man 8 mount** — The manual page for the **mount** command that provides a full documentation on its usage.
- **man 8 umount** — The manual page for the **umount** command that provides a full documentation on its usage.
- **man 8 findmnt** — The manual page for the **findmnt** command that provides a full documentation on its usage.
- **man 5 fstab** — The manual page providing a thorough description of the **/etc/fstab** file format.

18.4.2. Useful Websites

- *Shared subtrees* — An LWN article covering the concept of shared subtrees.

Chapter 19. The `volume_key` function

The volume_key function provides two tools, libvolume_key and **`volume_key`**. libvolume_key is a library for manipulating storage volume encryption keys and storing them separately from volumes. **`volume_key`** is an associated command line tool used to extract keys and passphrases in order to restore access to an encrypted hard drive.

This is useful for when the primary user forgets their keys and passwords, after an employee leaves abruptly, or in order to extract data after a hardware or software failure corrupts the header of the encrypted volume. In a corporate setting, the IT help desk can use **`volume_key`** to back up the encryption keys before handing over the computer to the end user.

Currently, **`volume_key`** only supports the LUKS volume encryption format.

Note

`volume_key` is not included in a standard install of Red Hat Enterprise Linux 6 server. For information on installing it, refer to http://fedoraproject.org/wiki/Disk_encryption_key_escrow_use_cases.

19.1. Commands

The format for **`volume_key`** is:

```
volume_key [OPTION]... OPERAND
```

The operands and mode of operation for **`volume_key`** are determined by specifying one of the following options:

`--save`

This command expects the operand *volume* [*packet*]. If a *packet* is provided then **`volume_key`** will extract the keys and passphrases from it. If *packet* is not provided, then **`volume_key`** will extract the keys and passphrases from the *volume*, prompting the user where necessary. These keys and passphrases will then be stored in one or more output packets.

`--restore`

This command expects the operands *volume packet*. It then opens the *volume* and uses the keys and passphrases in the *packet* to make the *volume* accessible again, prompting the user where necessary, such as allowing the user to enter a new passphrase, for example.

`--setup-volume`

This command expects the operands *volume packet name*. It then opens the *volume* and uses the keys and passphrases in the *packet* to set up the *volume* for use of the decrypted data as *name*.

Name is the name of a dm-crypt volume. This operation makes the decrypted volume available as **`/dev/mapper/`*`name`***.

This operation does not permanently alter the *volume* by adding a new passphrase, for example. The user can access and modify the decrypted volume, modifying *volume* in the process.

--reencrypt, --secrets, and --dump

These three commands perform similar functions with varying output methods. They each require the operand *packet*, and each opens the *packet*, decrypting it where necessary. **--reencrypt** then stores the information in one or more new output packets. **--secrets** outputs the keys and passphrases contained in the *packet*. **--dump** outputs the content of the *packet*, though the keys and passphrases are not output by default. This can be changed by appending **--with-secrets** to the command. It is also possible to only dump the unencrypted parts of the packet, if any, by using the **--unencrypted** command. This does not require any passphrase or private key access.

Each of these can be appended with the following options:

-o, --output *packet*

This command writes the default key or passphrase to the *packet*. The default key or passphrase depends on the volume format. Ensure it is one that is unlikely to expire, and will allow **--restore** to restore access to the volume.

--output-format *format*

This command uses the specified *format* for all output packets. Currently, *format* can be one of the following:

- **asymmetric**: uses CMS to encrypt the whole packet, and requires a certificate
- **asymmetric_wrap_secret_only**: wraps only the secret, or keys and passphrases, and requires a certificate
- **passphrase**: uses GPG to encrypt the whole packet, and requires a passphrase

--create-random-passphrase *packet*

This command generates a random alphanumeric passphrase, adds it to the *volume* (without affecting other passphrases), and then stores this random passphrase into the *packet*.

19.2. Using volume_key as an individual user

As an individual user, **volume_key** can be used to save encryption keys by using the following procedure.

Note

For all examples in this file, ***/path/to/volume*** is a LUKS device, not the plaintext device contained within. **blkid -s *type* /path/to/volume** should report ***type*="crypto_LUKS"**.

Procedure 19.1. Using volume_key stand-alone

1. Run:

```
volume_key --save /path/to/volume -o escrow-packet
```

A prompt will then appear requiring an escrow packet passphrase to protect the key.

2. Save the generated **escrow-packet** file, ensuring that the passphrase is not forgotten.

If the volume passphrase is forgotten, use the saved escrow packet to restore access to the data.

Procedure 19.2. Restore access to data with escrow packet

1. Boot the system in an environment where **volume_key** can be run and the escrow packet is available (a rescue mode, for example).
2. Run:

```
volume_key --restore /path/to/volume escrow-packet
```

A prompt will appear for the escrow packet passphrase that was used when creating the escrow packet, and for the new passphrase for the volume.

3. Mount the volume using the chosen passphrase.

To free up the passphrase slot in the LUKS header of the encrypted volume, remove the old, forgotten passphrase by using the command **cryptsetup luksKillSlot**.

19.3. Using volume_key in a larger organization

In a larger organization, using a single password known by every system administrator and keeping track of a separate password for each system is impractical and a security risk. To counter this, **volume_key** can use asymmetric cryptography to minimize the number of people who know the password required to access encrypted data on any computer.

This section will cover the procedures required for preparation before saving encryption keys, how to save encryption keys, restoring access to a volume, and setting up emergency passphrases.

19.3.1. Preparation for saving encryption keys

In order to begin saving encryption keys, some preparation is required.

Procedure 19.3. Preparation

1. Create an X509 certificate/private pair.
2. Designate trusted users who are trusted not to compromise the private key. These users will be able to decrypt the escrow packets.
3. Choose which systems will be used to decrypt the escrow packets. On these systems, set up an NSS database that contains the private key.

   If the private key was not created in an NSS database, follow these steps:

   A. Store the certificate and private key in an **PKCS#12** file.

   B. Run:

```
certutil -d /the/nss/directory -N
```

At this point it is possible to choose an NSS database password. Each NSS database can have a different password so the designated users do not need to share a single password if a separate NSS database is used by each user.

C. Run:

```
pk12util -d /the/nss/directory -i the-pkcs12-file
```

4. Distribute the certificate to anyone installing systems or saving keys on existing systems.

5. For saved private keys, prepare storage that allows them to be looked up by machine and volume. For example, this can be a simple directory with one subdirectory per machine, or a database used for other system management tasks as well.

19.3.2. Saving encryption keys

After completing the required preparation (see Section 19.3.1, “Preparation for saving encryption keys”) it is now possible to save the encryption keys using the following procedure.

Note

For all examples in this file, **/path/to/volume** is a LUKS device, not the plaintext device contained within; **blkid -s *type* */path/to/volume*** should report ***type*="crypto_LUKS"**.

Procedure 19.4. Saving encryption keys

1. Run:

```
volume_key --save /path/to/volume -c /path/to/cert escrow-packet
```

2. Save the generated **escrow-packet** file in the prepared storage, associating it with the system and the volume.

These steps can be performed manually, or scripted as part of system installation.

19.3.3. Restoring access to a volume

After the encryption keys have been saved (see Section 19.3.1, “Preparation for saving encryption keys” and Section 19.3.2, “Saving encryption keys”), access can be restored to a driver where needed.

Procedure 19.5. Restoring access to a volume

1. Get the escrow packet for the volume from the packet storage and send it to one of the designated users for decryption.

2. The designated user runs:

```
volume_key --reencrypt -d /the/nss/directory escrow-packet-in -o
escrow-packet-out
```

After providing the NSS database password, the designated user chooses a passphrase for encrypting **escrow-packet-out**. This passphrase can be different every time and only protects the encryption keys while they are moved from the designated user to the target system.

3. Obtain the **escrow-packet-out** file and the passphrase from the designated user.
4. Boot the target system in an environment that can run **volume_key** and have the **escrow-packet-out** file available, such as in a rescue mode.
5. Run:

```
volume_key --restore /path/to/volume escrow-packet-out
```

A prompt will appear for the packet passphrase chosen by the designated user, and for a new passphrase for the volume.

6. Mount the volume using the chosen volume passphrase.

It is possible to remove the old passphrase that was forgotten by using **cryptsetup luksKillSlot**, for example, to free up the passphrase slot in the LUKS header of the encrypted volume. This is done with the command **cryptsetup luksKillSlot *device key-slot***. For more information and examples see **cryptsetup --help**.

19.3.4. Setting up emergency passphrases

In some circumstances (such as traveling for business) it is impractical for system administrators to work directly with the affected systems, but users still need access to their data. In this case, **volume_key** can work with passphrases as well as encryption keys.

During the system installation, run:

```
volume_key --save /path/to/volume -c /path/to/ert --create-random-passphrase passphrase-packet
```

This generates a random passphrase, adds it to the specified volume, and stores it to ***passphrase-packet***. It is also possible to combine the **--create-random-passphrase** and **-o** options to generate both packets at the same time.

If a user forgets the password, the designated user runs:

```
volume_key --secrets -d /your/nss/directory passphrase-packet
```

This shows the random passphrase. Give this passphrase to the end user.

19.4. volume_key References

More information on **volume_key** can be found:

- in the readme file located at **/usr/share/doc/volume_key-*/README**
- on **volume_key**'s manpage using **man volume_key**
- online at http://fedoraproject.org/wiki/Disk_encryption_key_escrow_use_cases

Chapter 20. Access Control Lists

Files and directories have permission sets for the owner of the file, the group associated with the file, and all other users for the system. However, these permission sets have limitations. For example, different permissions cannot be configured for different users. Thus, *Access Control Lists* (ACLs) were implemented.

The Red Hat Enterprise Linux kernel provides ACL support for the ext3 file system and NFS-exported file systems. ACLs are also recognized on ext3 file systems accessed via Samba.

Along with support in the kernel, the **acl** package is required to implement ACLs. It contains the utilities used to add, modify, remove, and retrieve ACL information.

The **cp** and **mv** commands copy or move any ACLs associated with files and directories.

20.1. Mounting File Systems

Before using ACLs for a file or directory, the partition for the file or directory must be mounted with ACL support. If it is a local ext3 file system, it can mounted with the following command:

mount -t ext3 -o acl *device-name partition*

For example:

mount -t ext3 -o acl /dev/VolGroup00/LogVol02 /work

Alternatively, if the partition is listed in the **/etc/fstab** file, the entry for the partition can include the **acl** option:

```
LABEL=/work      /work       ext3    acl         1 2
```

If an ext3 file system is accessed via Samba and ACLs have been enabled for it, the ACLs are recognized because Samba has been compiled with the **--with-acl-support** option. No special flags are required when accessing or mounting a Samba share.

20.1.1. NFS

By default, if the file system being exported by an NFS server supports ACLs and the NFS client can read ACLs, then ACLs are utilized by the client system. To disable ACLs on NFS share when mounting it on a client, mount it with the **noacl** option with the command line.

20.2. Setting Access ACLs

There are two types of ACLs: *access ACLs* and *default ACLs*. An access ACL is the access control list for a specific file or directory. A default ACL can only be associated with a directory; if a file within the directory does not have an access ACL, it uses the rules of the default ACL for the directory. Default ACLs are optional.

ACLs can be configured:

1. Per user
2. Per group
3. Via the effective rights mask

4. For users not in the user group for the file

The **setfacl** utility sets ACLs for files and directories. Use the **-m** option to add or modify the ACL of a file or directory:

```
# setfacl -m rules files
```

Rules (*rules*) must be specified in the following formats. Multiple rules can be specified in the same command if they are separated by commas.

u:*uid*:*perms*

Sets the access ACL for a user. The user name or UID may be specified. The user may be any valid user on the system.

g:*gid*:*perms*

Sets the access ACL for a group. The group name or GID may be specified. The group may be any valid group on the system.

m:*perms*

Sets the effective rights mask. The mask is the union of all permissions of the owning group and all of the user and group entries.

o:*perms*

Sets the access ACL for users other than the ones in the group for the file.

Permissions (*perms*) must be a combination of the characters **r**, **w**, and **x** for read, write, and execute.

If a file or directory already has an ACL, and the **setfacl** command is used, the additional rules are added to the existing ACL or the existing rule is modified.

Example 20.1. Give read and write permissions

For example, to give read and write permissions to user andrius:

```
# setfacl -m u:andrius:rw /project/somefile
```

To remove all the permissions for a user, group, or others, use the **-x** option and do not specify any permissions:

```
# setfacl -x rules files
```

Example 20.2. Remove all permissions

For example, to remove all permissions from the user with UID 500:

```
# setfacl -x u:500 /project/somefile
```

20.3. Setting Default ACLs

To set a default ACL, add **d:** before the rule and specify a directory instead of a file name.

Example 20.3. Setting default ACLs

For example, to set the default ACL for the **/share/** directory to read and execute for users not in the user group (an access ACL for an individual file can override it):

```
# setfacl -m d:o:rx /share
```

20.4. Retrieving ACLs

To determine the existing ACLs for a file or directory, use the **getfacl** command. In the example below, the **getfacl** is used to determine the existing ACLs for a file.

Example 20.4. Retrieving ACLs

```
# getfacl home/john/picture.png
```

The above command returns the following output:

```
# file: home/john/picture.png
# owner: john
# group: john
user::rw-
group::r--
other::r--
```

If a directory with a default ACL is specified, the default ACL is also displayed as illustrated below. For example, **getfacl home/sales/** will display similar output:

```
# file: home/sales/
# owner: john
# group: john
user::rw-
user:barryg:r--
group::r--
mask::r--
other::r--
default:user::rwx
default:user:john:rwx
default:group::r-x
default:mask::rwx
default:other::r-x
```

20.5. Archiving File Systems With ACLs

By default, the **dump** command now preserves ACLs during a backup operation. When archiving a file or file system with **tar**, use the **--acls** option to preserve ACLs. Similarly, when using **cp** to copy files with ACLs, include the **--preserve=mode** option to ensure that ACLs are copied across too. In

addition, the **-a** option (equivalent to **-dR --preserve=all**) of **cp** also preserves ACLs during a backup along with other information such as timestamps, SELinux contexts, and the like. For more information about **dump**, **tar**, or **cp**, refer to their respective **man** pages.

The **star** utility is similar to the **tar** utility in that it can be used to generate archives of files; however, some of its options are different. Refer to Table 20.1, "Command Line Options for **star**" for a listing of more commonly used options. For all available options, refer to **man star**. The **star** package is required to use this utility.

Table 20.1. Command Line Options for star

Option	Description
-c	Creates an archive file.
-n	Do not extract the files; use in conjunction with **-x** to show what extracting the files does.
-r	Replaces files in the archive. The files are written to the end of the archive file, replacing any files with the same path and file name.
-t	Displays the contents of the archive file.
-u	Updates the archive file. The files are written to the end of the archive if they do not exist in the archive, or if the files are newer than the files of the same name in the archive. This option only works if the archive is a file or an unblocked tape that may backspace.
-x	Extracts the files from the archive. If used with **-U** and a file in the archive is older than the corresponding file on the file system, the file is not extracted.
-help	Displays the most important options.
-xhelp	Displays the least important options.
-/	Do not strip leading slashes from file names when extracting the files from an archive. By default, they are stripped when files are extracted.
-acl	When creating or extracting, archives or restores any ACLs associated with the files and directories.

20.6. Compatibility with Older Systems

If an ACL has been set on any file on a given file system, that file system has the **ext_attr** attribute. This attribute can be seen using the following command:

```
# tune2fs -l filesystem-device
```

A file system that has acquired the **ext_attr** attribute can be mounted with older kernels, but those kernels do not enforce any ACLs which have been set.

Versions of the **e2fsck** utility included in version 1.22 and higher of the **e2fsprogs** package (including the versions in Red Hat Enterprise Linux 2.1 and 4) can check a file system with the **ext_attr** attribute. Older versions refuse to check it.

20.7. ACL References

Refer to the following man pages for more information.

- **man acl** — Description of ACLs
- **man getfacl** — Discusses how to get file access control lists
- **man setfacl** — Explains how to set file access control lists
- **man star** — Explains more about the **star** utility and its many options

Chapter 21. Solid-State Disk Deployment Guidelines

Solid-state disks (SSD) are storage devices that use NAND flash chips to persistently store data. This sets them apart from previous generations of disks, which store data in rotating, magnetic platters. In an SSD, the access time for data across the full Logical Block Address (LBA) range is constant; whereas with older disks that use rotating media, access patterns that span large address ranges incur seek costs. As such, SSD devices have better latency and throughput.

Performance degrades as the number of used blocks approaches the disk capacity. The degree of performance impact varies greatly by vendor. However, all devices experience some degradation.

To address the degradation issue, the host system (for example, the Linux kernel) may use discard requests to inform the storage that a given range of blocks is no longer in use. An SSD can use this information to free up space internally, using the free blocks for wear-leveling. Discards will only be issued if the storage advertises support in terms of its storage protocol (be it ATA or SCSI). Discard requests are issued to the storage using the negotiated discard command specific to the storage protocol (**TRIM** command for ATA, and **WRITE SAME** with **UNMAP** set, or **UNMAP** command for SCSI).

Enabling **discard** support is most useful when there is available free space on the file system, but the file system has already written to most logical blocks on the underlying storage device. For more information about **TRIM**, refer to its *Data Set Management T13 Specifications* from the following link:

http://t13.org/Documents/UploadedDocuments/docs2008/e07154r6-Data_Set_Management_Proposal_for_ATA-ACS2.doc

For more information about **UNMAP**, refer to section 4.7.3.4 of the *SCSI Block Commands 3 T10 Specification* from the following link:

http://www.t10.org/cgi-bin/ac.pl?t=f&f=sbc3r26.pdf

Note

Not all solid-state devices in the market have **discard** support. To determine if your solid-state device has **discard** support check for **/sys/block/sda/queue/discard_granularity**.

21.1. Deployment Considerations

Because of the internal layout and operation of SSDs, it is best to partition devices on an internal *erase block boundary*. Partitioning utilities in Red Hat Enterprise Linux 6 chooses sane defaults if the SSD exports topology information.

However, if the device *does not* export topology information, Red Hat recommends that the first partition be created at a 1MB boundary.

In addition, keep in mind that **MD** (software raid) does not support discards. In contrast, the logical volume manager (LVM) and the device-mapper (DM) targets that LVM uses do support discards. The only DM targets that do not support discards are dm-snapshot, dm-crypt, and dm-raid45. Discard support for the dm-mirror was added in Red Hat Enterprise Linux 6.1.

Red Hat also warns that software RAID levels 1, 4, 5, and 6 are not recommended for use on SSDs. During the initialization stage of these RAID levels, some RAID management utilities (such as **mdadm**) write to *all* of the blocks on the storage device to ensure that checksums operate properly. This will cause the performance of the SSD to degrade quickly.

As of Red Hat Enterprise Linux 6.4, ext4 and XFS are the only fully-supported file systems that support **discard**. Previous versions of Red Hat Enterprise Linux 6 only ext4 fully supported **discard**. To enable **discard** commands on a device, use the **mount** option **discard**. For example, to mount **/dev/sda2** to **/mnt** with **discard** enabled, run:

```
# mount -t ext4 -o discard /dev/sda2 /mnt
```

By default, ext4 does not issue the **discard** command. This is mostly to avoid problems on devices which may not properly implement the **discard** command. The Linux **swap** code will issue **discard** commands to **discard**-enabled devices, and there is no option to control this behavior.

21.2. Tuning Considerations

This section describes several factors to consider when configuring settings that may affect SSD performance.

I/O Scheduler

Any I/O scheduler should perform well with most SSDs. However, as with any other storage type, Red Hat recommends benchmarking to determine the optimal configuration for a given workload.

When using SSDs, Red Hat advises changing the I/O scheduler only for benchmarking particular workloads. For more information about the different types of I/O schedulers, refer to the *I/O Tuning Guide* (also provided by Red Hat). The following kernel document also contains instructions on how to switch between I/O schedulers:

/usr/share/doc/kernel-*version*/Documentation/block/switching-sched.txt

Virtual Memory

Like the I/O scheduler, virtual memory (VM) subsystem requires no special tuning. Given the fast nature of I/O on SSD, it should be possible to turn down the **vm_dirty_background_ratio** and **vm_dirty_ratio** settings, as increased write-out activity should not negatively impact the latency of other operations on the disk. However, this can generate *more overall I/O* and so is not generally recommended without workload-specific testing.

Swap

An SSD can also be used as a swap device, and is likely to produce good page-out/page-in performance.

Chapter 22. Write Barriers

A *write barrier* is a kernel mechanism used to ensure that file system metadata is correctly written and ordered on persistent storage, even when storage devices with volatile write caches lose power. File systems with write barriers enabled also ensure that data transmitted via **fsync()** is persistent throughout a power loss.

Enabling write barriers incurs a substantial performance penalty for some applications. Specifically, applications that use **fsync()** heavily or create and delete many small files will likely run much slower.

22.1. Importance of Write Barriers

File systems take great care to safely update metadata, ensuring consistency. Journalled file systems bundle metadata updates into transactions and send them to persistent storage in the following manner:

1. First, the file system sends the body of the transaction to the storage device.
2. Then, the file system sends a commit block.
3. If the transaction and its corresponding commit block are written to disk, the file system assumes that the transaction will survive any power failure.

However, file system integrity during power failure becomes more complex for storage devices with extra caches. Storage target devices like local S-ATA or SAS drives may have write caches ranging from 32MB to 64MB in size (with modern drives). Hardware RAID controllers often contain internal write caches. Further, high end arrays, like those from NetApp, IBM, Hitachi and EMC (among others), also have large caches.

Storage devices with write caches report I/O as "complete" when the data is in cache; if the cache loses power, it loses its data as well. Worse, as the cache de-stages to persistent storage, it may change the original metadata ordering. When this occurs, the commit block may be present on disk without having the complete, associated transaction in place. As a result, the journal may replay these uninitialized transaction blocks into the file system during post-power-loss recovery; this will cause data inconsistency and corruption.

How Write Barriers Work

Write barriers are implemented in the Linux kernel via storage write cache flushes before and after the I/O, which is *order-critical*. After the transaction is written, the storage cache is flushed, the commit block is written, and the cache is flushed again. This ensures that:

- The disk contains all the data.
- No re-ordering has occurred.

With barriers enabled, an **fsync()** call will also issue a storage cache flush. This guarantees that file data is persistent on disk even if power loss occurs shortly after **fsync()** returns.

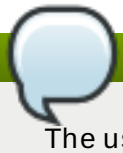
22.2. Enabling/Disabling Write Barriers

To mitigate the risk of data corruption during power loss, some storage devices use battery-backed write caches. Generally, high-end arrays and some hardware controllers use battery-backed write caches. However, because the cache's volatility is not visible to the kernel, Red Hat Enterprise Linux 6 enables write barriers by default on all supported journaling file systems.

For devices with non-volatile, battery-backed write caches and those with write-caching disabled, you can safely disable write barriers at mount time using the **-o nobarrier** option for **mount**. However, some devices do not support write barriers; such devices will log an error message to **/var/log/messages** (refer to Table 22.1, “Write barrier error messages per file system”).

Table 22.1. Write barrier error messages per file system

File System	Error Message
ext3/ext4	**JBD: barrier-based sync failed on *device* - disabling barriers**
XFS	**Filesystem *device* - Disabling barriers, trial barrier write failed**
btrfs	**btrfs: disabling barriers on dev *device***



Note

The use of **nobarrier** is no longer recommended in Red Hat Enterprise Linux 6 as the negative performance impact of write barriers is negligible (approximately 3%). The benefits of write barriers typically outweigh the performance benefits of disabling them. Additionally, the **nobarrier** option should never be used on storage configured on virtual machines.

22.3. Write Barrier Considerations

Some system configurations do not need write barriers to protect data. In most cases, other methods are preferable to write barriers, since enabling write barriers causes a significant performance penalty.

Disabling Write Caches

One way to alternatively avoid data integrity issues is to ensure that no write caches lose data on power failures. When possible, the best way to configure this is to simply disable the write cache. On a simple server or desktop with one or more SATA drives (off a local SATA controller Intel AHCI part), you can disable the write cache on the target SATA drives with the **hdparm** command, as in:

```
# hdparm -W0 /device/
```

Battery-Backed Write Caches

Write barriers are also unnecessary whenever the system uses hardware RAID controllers with battery-backed write cache. If the system is equipped with such controllers and if its component drives have write caches disabled, the controller will advertise itself as a write-through cache; this will inform the kernel that the write cache data will survive a power loss.

Most controllers use vendor-specific tools to query and manipulate target drives. For example, the LSI Megaraid SAS controller uses a battery-backed write cache; this type of controller requires the **MegaCli64** tool to manage target drives. To show the state of all back-end drives for LSI Megaraid SAS, use:

```
# MegaCli64 -LDGetProp  -DskCache  -LAll -aALL
```

To disable the write cache of all back-end drives for LSI Megaraid SAS, use:

```
# MegaCli64 -LDSetProp -DisDskCache -Lall -aALL
```

Note

Hardware RAID cards recharge their batteries while the system is operational. If a system is powered off for an extended period of time, the batteries will lose their charge, leaving stored data vulnerable during a power failure.

High-End Arrays

High-end arrays have various ways of protecting data in the event of a power failure. As such, there is no need to verify the state of the internal drives in external RAID storage.

NFS

NFS clients do not need to enable write barriers, since data integrity is handled by the NFS server side. As such, NFS servers should be configured to ensure data persistence throughout a power loss (whether through write barriers or other means).

Chapter 23. Storage I/O Alignment and Size

Recent enhancements to the SCSI and ATA standards allow storage devices to indicate their preferred (and in some cases, required) *I/O alignment* and *I/O size*. This information is particularly useful with newer disk drives that increase the physical sector size from 512 bytes to 4k bytes. This information may also be beneficial for RAID devices, where the chunk size and stripe size may impact performance.

The Linux I/O stack has been enhanced to process vendor-provided I/O alignment and I/O size information, allowing storage management tools (**parted**, **lvm**, **mkfs.***, and the like) to optimize data placement and access. If a legacy device does not export I/O alignment and size data, then storage management tools in Red Hat Enterprise Linux 6 will conservatively align I/O on a 4k (or larger power of 2) boundary. This will ensure that 4k-sector devices operate correctly even if they do not indicate any required/preferred I/O alignment and size.

Refer to Section 23.2, “Userspace Access” to learn how to determine the information that the operating system obtained from the device. This data is subsequently used by the storage management tools to determine data placement.

The IO scheduler has changed for Red Hat Enterprise Linux 7. Default IO Scheduler is now *Deadline*, except for SATA drives. CFQ is the default IO scheduler for SATA drives. For faster storage, Deadline outperforms CFQ and when it is used there is a performance increase without the need of special tuning.

If default is not right for some disks (for example, SAS rotational disks), then change the IO scheduler to CFQ. This instance will depend on the workload.

23.1. Parameters for Storage Access

The operating system uses the following information to determine I/O alignment and size:

physical_block_size

Smallest internal unit on which the device can operate

logical_block_size

Used externally to address a location on the device

alignment_offset

Tthe number of bytes that the beginning of the Linux block device (partition/MD/LVM device) is offset from the underlying physical alignment

minimum_io_size

The device’s preferred minimum unit for random I/O

optimal_io_size

The device’s preferred unit for streaming I/O

For example, certain 4K sector devices may use a 4K **physical_block_size** internally but expose a more granular 512-byte **logical_block_size** to Linux. This discrepancy introduces potential for misaligned I/O. To address this, the Red Hat Enterprise Linux 6 I/O stack will attempt to start all data areas on a naturally-aligned boundary (**physical_block_size**) by making sure it accounts for any alignment_offset if the beginning of the block device is offset from the underlying physical alignment.

Storage vendors can also supply *I/O hints* about the preferred minimum unit for random I/O (**minimum_io_size**) and streaming I/O (**optimal_io_size**) of a device. For example, **minimum_io_size** and **optimal_io_size** may correspond to a RAID device's chunk size and stripe size respectively.

23.2. Userspace Access

Always take care to use properly aligned and sized I/O. This is especially important for Direct I/O access. Direct I/O should be aligned on a **logical_block_size** boundary, and in multiples of the **logical_block_size**.

With native 4K devices (i.e. **logical_block_size** is 4K) it is now critical that applications perform direct I/O in multiples of the device's **logical_block_size**. This means that applications will fail with native 4k devices that perform 512-byte aligned I/O rather than 4k-aligned I/O.

To avoid this, an application should consult the I/O parameters of a device to ensure it is using the proper I/O alignment and size. As mentioned earlier, I/O parameters are exposed through the both **sysfs** and block device **ioctl** interfaces.

For more details, refer to **man libblkid**. This **man** page is provided by the **libblkid-devel** package.

sysfs Interface

- /sys/block/***disk***/alignment_offset
- /sys/block/***disk***/***partition***/alignment_offset
- /sys/block/***disk***/queue/physical_block_size
- /sys/block/***disk***/queue/logical_block_size
- /sys/block/***disk***/queue/minimum_io_size
- /sys/block/***disk***/queue/optimal_io_size

The kernel will still export these **sysfs** attributes for "legacy" devices that do not provide I/O parameters information, for example:

Example 23.1. sysfs interface

```
alignment_offset:    0
physical_block_size: 512
logical_block_size:  512
minimum_io_size:     512
optimal_io_size:     0
```

Block Device ioctls

- **BLKALIGNOFF**: **alignment_offset**
- **BLKPBSZGET**: **physical_block_size**

- **BLKSSZGET**: **logical_block_size**
- **BLKIOMIN**: **minimum_io_size**
- **BLKIOOPT**: **optimal_io_size**

23.3. Standards

This section describes I/O standards used by ATA and SCSI devices.

ATA

ATA devices must report appropriate information via the **IDENTIFY DEVICE** command. ATA devices only report I/O parameters for **physical_block_size**, **logical_block_size**, and **alignment_offset**. The additional I/O hints are outside the scope of the ATA Command Set.

SCSI

I/O parameters support in Red Hat Enterprise Linux 6 requires at least *version 3* of the *SCSI Primary Commands* (SPC-3) protocol. The kernel will only send an *extended inquiry* (which gains access to the **BLOCK LIMITS VPD** page) and **READ CAPACITY(16)** command to devices which claim compliance with SPC-3.

The **READ CAPACITY(16)** command provides the block sizes and alignment offset:

- **LOGICAL BLOCK LENGTH IN BYTES** is used to derive **/sys/block/*disk*/queue/physical_block_size**
- **LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT** is used to derive **/sys/block/*disk*/queue/logical_block_size**
- **LOWEST ALIGNED LOGICAL BLOCK ADDRESS** is used to derive:
  - **/sys/block/*disk*/alignment_offset**
  - **/sys/block/*disk*/*partition*/alignment_offset**

The **BLOCK LIMITS VPD** page (**0xb0**) provides the I/O hints. It also uses **OPTIMAL TRANSFER LENGTH GRANULARITY** and **OPTIMAL TRANSFER LENGTH** to derive:

- **/sys/block/*disk*/queue/minimum_io_size**
- **/sys/block/*disk*/queue/optimal_io_size**

The **sg3_utils** package provides the **sg_inq** utility, which can be used to access the **BLOCK LIMITS VPD** page. To do so, run:

```
# sg_inq -p 0xb0 disk
```

23.4. Stacking I/O Parameters

All layers of the Linux I/O stack have been engineered to propagate the various I/O parameters up the stack. When a layer consumes an attribute or aggregates many devices, the layer must expose appropriate I/O parameters so that upper-layer devices or tools will have an accurate view of the storage as it transformed. Some practical examples are:

- Only one layer in the I/O stack should adjust for a non-zero **alignment_offset**; once a layer adjusts accordingly, it will export a device with an **alignment_offset** of zero.
- A striped Device Mapper (DM) device created with LVM must export a **minimum_io_size** and **optimal_io_size** relative to the stripe count (number of disks) and user-provided chunk size.

In Red Hat Enterprise Linux 6, Device Mapper and Software Raid (MD) device drivers can be used to arbitrarily combine devices with different I/O parameters. The kernel's block layer will attempt to reasonably combine the I/O parameters of the individual devices. The kernel will not prevent combining heterogeneous devices; however, be aware of the risks associated with doing so.

For instance, a 512-byte device and a 4K device may be combined into a single logical DM device, which would have a **logical_block_size** of 4K. File systems layered on such a hybrid device assume that 4K will be written atomically, but in reality it will span 8 logical block addresses when issued to the 512-byte device. Using a 4K **logical_block_size** for the higher-level DM device increases potential for a partial write to the 512-byte device if there is a system crash.

If combining the I/O parameters of multiple devices results in a conflict, the block layer may issue a warning that the device is susceptible to partial writes and/or is misaligned.

23.5. Logical Volume Manager

LVM provides userspace tools that are used to manage the kernel's DM devices. LVM will shift the start of the data area (that a given DM device will use) to account for a non-zero **alignment_offset** associated with any device managed by LVM. This means logical volumes will be properly aligned (**alignment_offset=0**).

By default, LVM will adjust for any **alignment_offset**, but this behavior can be disabled by setting **data_alignment_offset_detection** to **0** in **/etc/lvm/lvm.conf**. Disabling this is not recommended.

LVM will also detect the I/O hints for a device. The start of a device's data area will be a multiple of the **minimum_io_size** or **optimal_io_size** exposed in sysfs. LVM will use the **minimum_io_size** if **optimal_io_size** is undefined (i.e. **0**).

By default, LVM will automatically determine these I/O hints, but this behavior can be disabled by setting **data_alignment_detection** to **0** in **/etc/lvm/lvm.conf**. Disabling this is not recommended.

23.6. Partition and File System Tools

This section describes how different partition and file system management tools interact with a device's I/O parameters.

util-linux-ng's libblkid and fdisk

The **libblkid** library provided with the **util-linux-ng** package includes a programmatic API to access a device's I/O parameters. **libblkid** allows applications, especially those that use Direct I/O, to properly size their I/O requests. The **fdisk** utility from **util-linux-ng** uses **libblkid** to

determine the I/O parameters of a device for optimal placement of all partitions. The **fdisk** utility will align all partitions on a 1MB boundary.

parted and libparted

The **libparted** library from **parted** also uses the I/O parameters API of **libblkid**. The Red Hat Enterprise Linux 6 installer (**Anaconda**) uses **libparted**, which means that all partitions created by either the installer or **parted** will be properly aligned. For all partitions created on a device that does not appear to provide I/O parameters, the default alignment will be 1MB.

The heuristics **parted** uses are as follows:

- Always use the reported **alignment_offset** as the offset for the start of the first primary partition.
- If **optimal_io_size** is defined (i.e. not **0**), align all partitions on an **optimal_io_size** boundary.
- If **optimal_io_size** is undefined (i.e. **0**), **alignment_offset** is **0**, and **minimum_io_size** is a power of 2, use a 1MB default alignment.

  This is the catch-all for "legacy" devices which don't appear to provide I/O hints. As such, by default all partitions will be aligned on a 1MB boundary.

Note

Red Hat Enterprise Linux 6 cannot distinguish between devices that don't provide I/O hints and those that do so with **alignment_offset=0** and **optimal_io_size=0**. Such a device might be a single SAS 4K device; as such, at worst 1MB of space is lost at the start of the disk.

File System tools

The different **mkfs.*filesystem*** utilities have also been enhanced to consume a device's I/O parameters. These utilities will not allow a file system to be formatted to use a block size smaller than the **logical_block_size** of the underlying storage device.

Except for **mkfs.gfs2**, all other **mkfs.*filesystem*** utilities also use the I/O hints to layout on-disk data structure and data areas relative to the **minimum_io_size** and **optimal_io_size** of the underlying storage device. This allows file systems to be optimally formatted for various RAID (striped) layouts.

Chapter 24. Setting Up A Remote Diskless System

The Network Booting Service (provided by **system-config-netboot**) is no longer available in Red Hat Enterprise Linux 6. Deploying diskless systems is now possible in this release without the use of **system-config-netboot**.

To set up a basic remote diskless system booted over PXE, you need the following packages:

- **tftp-server**
- **xinetd**
- **dhcp**
- **syslinux**
- **dracut-network**

Remote diskless system booting requires both a **tftp** service (provided by **tftp-server**) and a DHCP service (provided by **dhcp**). The **tftp** service is used to retrieve kernel image and **initrd** over the network via the PXE loader.

The following sections outline the necessary procedures for deploying remote diskless systems in a network environment.

24.1. Configuring a tftp Service for Diskless Clients

The **tftp** service is disabled by default. To enable it and allow PXE booting via the network, set the **Disabled** option in **/etc/xinetd.d/tftp** to **no**. To configure **tftp**, perform the following steps:

Procedure 24.1. To configure tftp

1. The **tftp** root directory (**chroot**) is located in **/var/lib/tftpboot**. Copy **/usr/share/syslinux/pxelinux.0** to **/var/lib/tftpboot/**, as in:

   ```
   cp /usr/share/syslinux/pxelinux.0 /var/lib/tftpboot/
   ```

2. Create a **pxelinux.cfg** directory inside the **tftp** root directory:

   ```
   mkdir -p /var/lib/tftpboot/pxelinux.cfg/
   ```

You will also need to configure firewall rules properly to allow **tftp** traffic; as **tftp** supports TCP wrappers, you can configure host access to **tftp** via **/etc/hosts.allow**. For more information on configuring TCP wrappers and the **/etc/hosts.allow** configuration file, refer to the Red Hat Enterprise Linux 6 *Security Guide*; **man hosts_access** also provides information about **/etc/hosts.allow**.

After configuring **tftp** for diskless clients, configure DHCP, NFS, and the exported file system accordingly. Refer to Section 24.2, “Configuring DHCP for Diskless Clients” and Section 24.3, “Configuring an Exported File System for Diskless Clients” for instructions on how to do so.

24.2. Configuring DHCP for Diskless Clients

After configuring a **tftp** server, you need to set up a DHCP service on the same host machine. Refer to the Red Hat Enterprise Linux 6 *Deployment Guide* for instructions on how to set up a DHCP server. In addition, you should enable PXE booting on the DHCP server; to do this, add the following configuration to **/etc/dhcp/dhcp.conf**:

```
allow booting;
allow bootp;
class "pxeclients" {
   match if substring(option vendor-class-identifier, 0, 9) =
"PXEClient";
   next-server server-ip;
   filename "pxelinux.0";
}
```

Replace ***server-ip*** with the IP address of the host machine on which the **tftp** and DHCP services reside. Now that **tftp** and DHCP are configured, all that remains is to configure NFS and the exported file system; refer to Section 24.3, “Configuring an Exported File System for Diskless Clients” for instructions.

24.3. Configuring an Exported File System for Diskless Clients

The root directory of the exported file system (used by diskless clients in the network) is shared via NFS. Configure the NFS service to export the root directory by adding it to **/etc/exports**. For instructions on how to do so, refer to Section 9.7.1, “The **/etc/exports** Configuration File”.

To accommodate completely diskless clients, the root directory should contain a complete Red Hat Enterprise Linux installation. You can synchronize this with a running system via **rsync**, as in:

```
# rsync -a -e ssh --exclude='/proc/*' --exclude='/sys/*' hostname.com:/
/exported/root/directory
```

Replace ***hostname.com*** with the hostname of the running system with which to synchronize via **rsync**. The ***/exported/root/directory*** is the path to the exported file system.

Alternatively, you can also use **yum** with the **--installroot** option to install Red Hat Enterprise Linux to a specific location. For example:

```
yum groupinstall Base --installroot=/exported/root/directory
```

The file system to be exported still needs to be configured further before it can be used by diskless clients. To do this, perform the following procedure:

Procedure 24.2. Configure file system

1. Configure the exported file system's **/etc/fstab** to contain (at least) the following configuration:

   ```
   none  /tmp  tmpfs defaults 0 0
   tmpfs  /dev/shm tmpfs defaults 0 0
   sysfs  /sys  sysfs defaults 0 0
   proc  /proc  proc  defaults 0 0
   ```

2. Select the kernel that diskless clients should use (**vmlinuz-*kernel-version***) and copy it to the **tftp** boot directory:

```
# cp /boot/vmlinuz-kernel-version /var/lib/tftpboot/
```

3. Create the **initrd** (i.e. **initramfs-*kernel-version*.img**) with network support:

   ```
   # dracut initramfs-kernel-version.img kernel-version
   ```

   Copy the resulting **initramfs-*kernel-version*.img** into the **tftp** boot directory as well.

4. Edit the default boot configuration to use the **initrd** and kernel inside **/var/lib/tftpboot**. This configuration should instruct the diskless client's root to mount the exported file system (**/*exported/root/directory***) as read-write. To do this, configure **/var/lib/tftpboot/pxelinux.cfg/default** with the following:

   ```
   default rhel6

   label rhel6
     kernel vmlinuz-kernel-version
     append initrd=initramfs-kernel-version.img root=nfs:server-
   ip:/exported/root/directory rw
   ```

   Replace ***server-ip*** with the IP address of the host machine on which the **tftp** and DHCP services reside.

The NFS share is now ready for exporting to diskless clients. These clients can boot over the network via PXE.

Chapter 25. Online Storage Management

It is often desirable to add, remove or re-size storage devices while the operating system is running, and without rebooting. This chapter outlines the procedures that may be used to reconfigure storage devices on Red Hat Enterprise Linux 6 host systems while the system is running. It covers iSCSI and Fibre Channel storage interconnects; other interconnect types may be added it the future.

This chapter focuses on adding, removing, modifying, and monitoring storage devices. It does not discuss the Fibre Channel or iSCSI protocols in detail. For more information about these protocols, refer to other documentation.

This chapter makes reference to various **sysfs** objects. Red Hat advises that the **sysfs** object names and directory structure are subject to change in major Red Hat Enterprise Linux releases. This is because the upstream Linux kernel does not provide a stable internal API. For guidelines on how to reference **sysfs** objects in a transportable way, refer to the document **/usr/share/doc/kernel-doc-*version*/Documentation/sysfs-rules.txt** in the kernel source tree for guidelines.

Warning

Online storage reconfiguration must be done carefully. System failures or interruptions during the process can lead to unexpected results. Red Hat advises that you reduce system load to the maximum extent possible during the change operations. This will reduce the chance of I/O errors, out-of-memory errors, or similar errors occurring in the midst of a configuration change. The following sections provide more specific guidelines regarding this.

In addition, Red Hat recommends that you back up all data before reconfiguring online storage.

25.1. Fibre Channel

This section discusses the Fibre Channel API, native Red Hat Enterprise Linux 6 Fibre Channel drivers, and the Fibre Channel capabilities of these drivers.

25.1.1. Fibre Channel API

Below is a list of **/sys/class/** directories that contain files used to provide the userspace API. In each item, host numbers are designated by ***H***, bus numbers are ***B***, targets are ***T***, logical unit numbers (LUNs) are ***L***, and remote port numbers are ***R***.

Important

If your system is using multipath software, Red Hat recommends that you consult your hardware vendor before changing any of the values described in this section.

Transport: /sys/class/fc_transport/target*H*:*B*:*T*/

- **port_id** — 24-bit port ID/address
- **node_name** — 64-bit node name

- **port_name** — 64-bit port name

Remote Port: /sys/class/fc_remote_ports/rport-*H*:*B*-*R*/

- **port_id**
- **node_name**
- **port_name**
- **dev_loss_tmo** — number of seconds to wait before marking a link as "bad". Once a link is marked bad, I/O running on its corresponding path (along with any new I/O on that path) will be failed.

  The default **dev_loss_tmo** value varies, depending on which driver/device is used. If a Qlogic adapter is used, the default is 35 seconds, while if an Emulex adapter is used, it is 30 seconds. The **dev_loss_tmo** value can be changed via the **scsi_transport_fc** module parameter **dev_loss_tmo**, although the driver can override this timeout value.

  The maximum **dev_loss_tmo** value is 600 seconds. If **dev_loss_tmo** is set to zero or any value greater than 600, the driver's internal timeouts will be used instead.
- **fast_io_fail_tmo** — length of time to wait before failing I/O executed when a link problem is detected. I/O that reaches the driver will fail. If I/O is in a blocked queue, it will not be failed until **dev_loss_tmo** expires and the queue is unblocked.

Host: /sys/class/fc_host/host*H*/

- **port_id**
- **issue_lip** — instructs the driver to rediscover remote ports.

25.1.2. Native Fibre Channel Drivers and Capabilities

Red Hat Enterprise Linux 6 ships with the following native fibre channel drivers:

- **lpfc**
- **qla2xxx**
- **zfcp**
- **mptfc**
- **bfa**

Table 25.1, “Fibre-Channel API Capabilities” describes the different fibre-channel API capabilities of each native Red Hat Enterprise Linux 6 driver. X denotes support for the capability.

Table 25.1. Fibre-Channel API Capabilities

	lpfc	qla2xxx	zfcp	mptfc	bfa
Transport **port_id**	X	X	X	X	X
Transport **node_name**	X	X	X	X	X
Transport **port_name**	X	X	X	X	X

	lpfc	qla2xxx	zfcp	mptfc	bfa
Remote Port **dev_loss_tmo**	X	X	X	X	X
Remote Port **fast_io_fail_tmo**	X	X [a]	X [b]		X
Host **port_id**	X	X	X	X	X
Host **issue_lip**	X	X			X

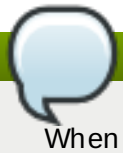
[a] Supported as of Red Hat Enterprise Linux 5.4
[b] Supported as of Red Hat Enterprise Linux 6.0

25.2. iSCSI

This section describes the iSCSI API and the **iscsiadm** utility. Before using the **iscsiadm** utility, install the **iscsi-initiator-utils** package first by running **yum install iscsi-initiator-utils**.

In Red Hat Enterprise Linux 6, the iSCSI service is lazily started by default. If root is not on an iSCSI device or there are no nodes marked with **node.startup = automatic** then the iSCSI service will not start until an **iscsiadm** command is run that requires iscsid or the iscsi kernel modules to be started. For example, running the discovery command **iscsiadm -m discovery -t st -p ip:port** will cause iscsiadmin to start the iSCSI service.

To force the iscsid daemon to run and iSCSI kernel modules to load, run **service iscsid force-start**.



Note

When using the hal daemon with a large number of iSCSI LUNs, over several thousand, the **--child-timeout** option should be used in order to avoid boot failures. The **--child-timeout** option sets the number of seconds to wait for all disk probes to run. For example, to force the hal daemon to wait 10 minutes and 30 seconds, the option would read **--child-timeout=630**. The default time is 250 seconds. While this means the hal daemon will take longer to start, it will give enough time for all disk devices to be recognized and avoid boot failures.

The reason for this work around is because in 2003 when the hal daemon was created, it was unusual to have more than a dozen iSCSI disks. It is for this reason, the hal daemon has been removed in Red Hat Enterprise Linux 7 and replaced with udisks.

For more information refer to the knowledgebase article located at https://access.redhat.com/solutions/27571.

25.2.1. iSCSI API

To get information about running sessions, run:

```
# iscsiadm -m session -P 3
```

This command displays the session/device state, session ID (sid), some negotiated parameters, and the SCSI devices accessible through the session.

For shorter output (for example, to display only the sid-to-node mapping), run:

```
# iscsiadm -m session -P 0
```

or

```
# iscsiadm -m session
```

These commands print the list of running sessions with the format:

```
driver [sid] target_ip:port,target_portal_group_tag proper_target_name
```

Example 25.1. Output of the `iscsiadm -m session` command

For example:

```
# iscsiadm -m session

tcp [2] 10.15.84.19:3260,2 iqn.1992-08.com.netapp:sn.33615311
tcp [3] 10.15.85.19:3260,3 iqn.1992-08.com.netapp:sn.33615311
```

For more information about the iSCSI API, refer to **/usr/share/doc/iscsi-initiator-utils-*version*/README**.

25.2.2. iSCSI Target Set up

Add a new target

To add a new iSCSI target edit the **/etc/tgt/targets.conf** configuration file. This file contains many examples of different configuration options that have been commented out.

A basic target may be defined as:

Example 25.2. A basic target

```
<target iqn.2008-09.com.example:server.target1>
    backing-store /srv/images/iscsi-share.img
    direct-store /dev/sdd
</target>
```

This example defines a single target with two LUNs. LUNs are described with either the *backing-store* or *direct-store* directives where backing-store refers to either a file or a block device, and direct-store refers to local SCSI devices. Device parameters, such as serial numbers and vendor names, will be passed through to the new iSCSI LUN.

Starting the tgtd service

To start the tgtd service, run:

```
service tgtd start
```

Stopping the tgtd service

To stop the tgtd service, run:

```
service tgtd stop
```

If there are open connections, use:

```
service tgtd force-stop
```

Warning

Using this command will terminate all target arrays.

25.3. Persistent Naming

The operating system issues I/O to a storage device by referencing the path that is used to reach it. For SCSI devices, the path consists of the following:

- PCI identifier of the host bus adapter (HBA)
- channel number on that HBA
- the remote SCSI target address
- the Logical Unit Number (LUN)

This path-based address is not persistent. It may change any time the system is reconfigured (either by on-line reconfiguration, as described in this manual, or when the system is shutdown, reconfigured, and rebooted). It is even possible for the path identifiers to change when no physical reconfiguration has been done, as a result of timing variations during the discovery process when the system boots, or when a bus is re-scanned.

The operating system provides several non-persistent names to represent these access paths to storage devices. One is the **/dev/sd** name; another is the **major:minor** number. A third is a symlink maintained in the **/dev/disk/by-path/** directory. This symlink maps from the path identifier to the current **/dev/sd** name. For example, for a Fibre Channel device, the PCI info and ***Host*:*BusTarget*:*LUN*** info may appear as follows:

```
pci-0000:02:0e.0-scsi-0:0:0:0 -> ../../sda
```

For iSCSI devices, **by-path/** names map from the target name and portal information to the **sd** name.

It is generally *not* appropriate for applications to use these path-based names. This is because the storage device these paths reference may change, potentially causing incorrect data to be written to the device. Path-based names are also not appropriate for multipath devices, because the path-based names may be mistaken for separate storage devices, leading to uncoordinated access and unintended modifications of the data.

In addition, path-based names are system-specific. This can cause unintended data changes when the device is accessed by multiple systems, such as in a cluster.

For these reasons, several persistent, system-independent, methods for identifying devices have been developed. The following sections discuss these in detail.

25.3.1. WWID

The *World Wide Identifier* (WWID) can be used in reliably identifying devices. It is a persistent, system-independent ID that the SCSI Standard requires from all SCSI devices. The WWID identifier is guaranteed to be unique for every storage device, and independent of the path that is used to access the device.

This identifier can be obtained by issuing a SCSI Inquiry to retrieve the *Device Identification Vital Product Data* (page **0x83**) or *Unit Serial Number* (page **0x80**). The mappings from these WWIDs to the current **/dev/sd** names can be seen in the symlinks maintained in the **/dev/disk/by-id/** directory.

Example 25.3. WWID

For example, a device with a page **0x83** identifier would have:

```
scsi-3600508b400105e210000900000490000 -> ../../sda
```

Or, a device with a page **0x80** identifier would have:

```
scsi-SSEAGATE_ST373453LW_3HW1RHM6 -> ../../sda
```

Red Hat Enterprise Linux automatically maintains the proper mapping from the WWID-based device name to a current **/dev/sd** name on that system. Applications can use the **/dev/disk/by-id/** name to reference the data on the disk, even if the path to the device changes, and even when accessing the device from different systems.

If there are multiple paths from a system to a device, **device-mapper-multipath** uses the WWID to detect this. **Device-mapper-multipath** then presents a single "pseudo-device" in **/dev/mapper/wwid**, such as **/dev/mapper/3600508b400105df70000e00000ac0000**.

The command **multipath -l** shows the mapping to the non-persistent identifiers: ***Host*:*Channel*:*Target*:*LUN***, **/dev/sd** name, and the **major:minor** number.

```
3600508b400105df70000e00000ac0000 dm-2 vendor,product
[size=20G][features=1 queue_if_no_path][hwhandler=0][rw]
\_ round-robin 0 [prio=0][active]
 \_ 5:0:1:1 sdc 8:32  [active][undef]
 \_ 6:0:1:1 sdg 8:96  [active][undef]
\_ round-robin 0 [prio=0][enabled]
 \_ 5:0:0:1 sdb 8:16  [active][undef]
 \_ 6:0:0:1 sdf 8:80  [active][undef]
```

Device-mapper-multipath automatically maintains the proper mapping of each WWID-based device name to its corresponding **/dev/sd** name on the system. These names are persistent across path changes, and they are consistent when accessing the device from different systems.

When the **user_friendly_names** feature (of **device-mapper-multipath**) is used, the WWID is mapped to a name of the form **/dev/mapper/mpath*n***. By default, this mapping is maintained in the file **/etc/multipath/bindings**. These **mpathn** names are persistent as long as that file is maintained.

Important

If you use **user_friendly_names**, then additional steps are required to obtain consistent names in a cluster. Refer to the Consistent Multipath Device Names in a Cluster section in the *Using DM Multipath Configuration and Administration* book.

In addition to these persistent names provided by the system, you can also use **udev** rules to implement persistent names of your own, mapped to the WWID of the storage. For more information about this, refer to http://kbase.redhat.com/faq/docs/DOC-7319.

25.3.2. UUID and Other Persistent Identifiers

If a storage device contains a file system, then that file system may provide one or both of the following:

- *Universally Unique Identifier* (UUID)
- File system label

These identifiers are persistent, and based on metadata written on the device by certain applications. They may also be used to access the device using the symlinks maintained by the operating system in the **/dev/disk/by-label/** (e.g. **boot -> ../../sda1**) and **/dev/disk/by-uuid/** (e.g. **f8bf09e3-4c16-4d91-bd5e-6f62da165c08 -> ../../sda1**) directories.

md and LVM write metadata on the storage device, and read that data when they scan devices. In each case, the metadata contains a UUID, so that the device can be identified regardless of the path (or system) used to access it. As a result, the device names presented by these facilities are persistent, as long as the metadata remains unchanged.

25.4. Removing a Storage Device

Before removing access to the storage device itself, it is advisable to back up data from the device first. Afterwards, flush I/O and remove all operating system references to the device (as described below). If the device uses multipathing, then do this for the multipath "pseudo device" (Section 25.3.1, “WWID”) and each of the identifiers that represent a path to the device. If you are only removing a path to a multipath device, and other paths will remain, then the procedure is simpler, as described in Section 25.6, “Adding a Storage Device or Path”.

Removal of a storage device is not recommended when the system is under memory pressure, since the I/O flush will add to the load. To determine the level of memory pressure, run the command **vmstat 1 100**; device removal is not recommended if:

- Free memory is less than 5% of the total memory in more than 10 samples per 100 (the command **free** can also be used to display the total memory).
- Swapping is active (non-zero **si** and **so** columns in the **vmstat** output).

The general procedure for removing all access to a device is as follows:

Procedure 25.1. Ensuring a Clean Device Removal

1. Close all users of the device and backup device data as needed.
2. Use **umount** to unmount any file systems that mounted the device.
3. Remove the device from any **md** and LVM volume using it. If the device is a member of an LVM Volume group, then it may be necessary to move data off the device using the **pvmove** command, then use the **vgreduce** command to remove the physical volume, and (optionally) **pvremove** to remove the LVM metadata from the disk.
4. If the device uses multipathing, run **multipath -l** and note all the paths to the device. Afterwards, remove the multipathed device using **multipath -f device**.
5. Run **blockdev --flushbufs *device*** to flush any outstanding I/O to all paths to the device. This is particularly important for raw devices, where there is no **umount** or **vgreduce** operation to cause an I/O flush.
6. Remove any reference to the device's path-based name, like **/dev/sd**, **/dev/disk/by-path** or the **major:minor** number, in applications, scripts, or utilities on the system. This is important in ensuring that different devices added in the future will not be mistaken for the current device.
7. Finally, remove each path to the device from the SCSI subsystem. To do so, use the command **echo 1 > /sys/block/*device-name*/device/delete** where ***device-name*** may be **sde**, for example.

   Another variation of this operation is **echo 1 > /sys/class/scsi_device/*h*:*c*:*t*:*l*/device/delete**, where ***h*** is the HBA number, ***c*** is the channel on the HBA, ***t*** is the SCSI target ID, and ***l*** is the LUN.

Note

The older form of these commands, **echo "scsi remove-single-device 0 0 0 0" > /proc/scsi/scsi**, is deprecated.

You can determine the ***device-name***, HBA number, HBA channel, SCSI target ID and LUN for a device from various commands, such as **lsscsi**, **scsi_id**, **multipath -l**, and **ls -l /dev/disk/by-***.

After performing Procedure 25.1, “Ensuring a Clean Device Removal”, a device can be physically removed safely from a running system. It is not necessary to stop I/O to other devices while doing so.

Other procedures, such as the physical removal of the device, followed by a rescan of the SCSI bus (as described in Section 25.9, “Scanning Storage Interconnects”) to cause the operating system state to be updated to reflect the change, are not recommended. This will cause delays due to I/O timeouts, and devices may be removed unexpectedly. If it is necessary to perform a rescan of an interconnect, it must be done while I/O is paused, as described in Section 25.9, “Scanning Storage Interconnects”.

25.5. Removing a Path to a Storage Device

If you are removing a path to a device that uses multipathing (without affecting other paths to the device), then the general procedure is as follows:

Procedure 25.2. Removing a Path to a Storage Device

1. Remove any reference to the device's path-based name, like **/dev/sd** or **/dev/disk/by-path** or the **major:minor** number, in applications, scripts, or utilities on the system. This is important in ensuring that different devices added in the future will not be mistaken for the current device.

2. Take the path offline using **echo offline > /sys/block/sda/device/state**.

   This will cause any subsequent I/O sent to the device on this path to be failed immediately. **Device-mapper-multipath** will continue to use the remaining paths to the device.

3. Remove the path from the SCSI subsystem. To do so, use the command **echo 1 > /sys/block/*device-name*/device/delete** where ***device-name*** may be **sde**, for example (as described in Procedure 25.1, “Ensuring a Clean Device Removal”).

After performing Procedure 25.2, “Removing a Path to a Storage Device”, the path can be safely removed from the running system. It is not necessary to stop I/O while this is done, as **device-mapper-multipath** will re-route I/O to remaining paths according to the configured path grouping and failover policies.

Other procedures, such as the physical removal of the cable, followed by a rescan of the SCSI bus to cause the operating system state to be updated to reflect the change, are not recommended. This will cause delays due to I/O timeouts, and devices may be removed unexpectedly. If it is necessary to perform a rescan of an interconnect, it must be done while I/O is paused, as described in Section 25.9, “Scanning Storage Interconnects”.

25.6. Adding a Storage Device or Path

When adding a device, be aware that the path-based device name (**/dev/sd** name, **major:minor** number, and **/dev/disk/by-path** name, for example) the system assigns to the new device may have been previously in use by a device that has since been removed. As such, ensure that all old references to the path-based device name have been removed. Otherwise, the new device may be mistaken for the old device.

Procedure 25.3. Add a storage device or path

1. The first step in adding a storage device or path is to physically enable access to the new storage device, or a new path to an existing device. This is done using vendor-specific commands at the Fibre Channel or iSCSI storage server. When doing so, note the LUN value for the new storage that will be presented to your host. If the storage server is Fibre Channel, also take note of the *World Wide Node Name* (WWNN) of the storage server, and determine whether there is a single WWNN for all ports on the storage server. If this is not the case, note the *World Wide Port Name* (WWPN) for each port that will be used to access the new LUN.

2. Next, make the operating system aware of the new storage device, or path to an existing device. The recommended command to use is:

   ```
   $ echo "c t l" >  /sys/class/scsi_host/hosth/scan
   ```

   In the previous command, ***h*** is the HBA number, ***c*** is the channel on the HBA, ***t*** is the SCSI target ID, and ***l*** is the LUN.

Note

The older form of this command, **`echo "scsi add-single-device 0 0 0 0" > /proc/scsi/scsi`**, is deprecated.

a. In some Fibre Channel hardware, a newly created LUN on the RAID array may not be visible to the operating system until a *Loop Initialization Protocol* (LIP) operation is performed. Refer to Section 25.9, “Scanning Storage Interconnects” for instructions on how to do this.

Important

It will be necessary to stop I/O while this operation is executed if an LIP is required.

b. If a new LUN has been added on the RAID array but is still not being configured by the operating system, confirm the list of LUNs being exported by the array using the **`sg_luns`** command, part of the *sg3_utils* package. This will issue the **`SCSI REPORT LUNS`** command to the RAID array and return a list of LUNs that are present.

For Fibre Channel storage servers that implement a single WWNN for all ports, you can determine the correct ***h***,***c***,and ***t*** values (i.e. HBA number, HBA channel, and SCSI target ID) by searching for the WWNN in **`sysfs`**.

Example 25.4. Determin correct h, c, and t values

For example, if the WWNN of the storage server is **`0x5006016090203181`**, use:

```
$ grep 5006016090203181 /sys/class/fc_transport/*/node_name
```

This should display output similar to the following:

```
/sys/class/fc_transport/target5:0:2/node_name:0x5006016090203181
/sys/class/fc_transport/target5:0:3/node_name:0x5006016090203181
/sys/class/fc_transport/target6:0:2/node_name:0x5006016090203181
/sys/class/fc_transport/target6:0:3/node_name:0x5006016090203181
```

This indicates there are four Fibre Channel routes to this target (two single-channel HBAs, each leading to two storage ports). Assuming a LUN value is **`56`**, then the following command will configure the first path:

```
$ echo "0 2 56" >  /sys/class/scsi_host/host5/scan
```

This must be done for each path to the new device.

For Fibre Channel storage servers that do not implement a single WWNN for all ports, you can determine the correct HBA number, HBA channel, and SCSI target ID by searching for each of the WWPNs in **`sysfs`**.

Another way to determine the HBA number, HBA channel, and SCSI target ID is to refer to

another device that is already configured on the same path as the new device. This can be done with various commands, such as **lsscsi**, **scsi_id**, **multipath -l**, and **ls -l /dev/disk/by-***. This information, plus the LUN number of the new device, can be used as shown above to probe and configure that path to the new device.

3. After adding all the SCSI paths to the device, execute the **multipath** command, and check to see that the device has been properly configured. At this point, the device can be added to **md**, LVM, **mkfs**, or **mount**, for example.

If the steps above are followed, then a device can safely be added to a running system. It is not necessary to stop I/O to other devices while this is done. Other procedures involving a rescan (or a reset) of the SCSI bus, which cause the operating system to update its state to reflect the current device connectivity, are not recommended while storage I/O is in progress.

25.7. Configuring a Fibre-Channel Over Ethernet Interface

Setting up and deploying a Fibre-channel over Ethernet (FCoE) interface requires two packages:

- **fcoe-utils**
- **lldpad**

Once these packages are installed, perform the following procedure to enable FCoE over a virtual LAN (VLAN):

Procedure 25.4. Configuring an Ethernet interface to use FCoE

1. Configure a new VLAN by copying an existing network script (e.g. **/etc/fcoe/cfg-eth0**) to the name of the Ethernet device that supports FCoE. This will provide you with a default file to configure. Given that the FCoE device is **eth*X***, run:

```
# cp /etc/fcoe/cfg-eth0  /etc/fcoe/cfg-ethX
```

   Modify the contents of **cfg-eth*X*** as necessary. Of note, **DCB_REQUIRED** should be set to **no** for networking interfaces that implement a hardware DCBX client.

2. If you want the device to automatically load during boot time, set **ONBOOT=yes** in the corresponding **/etc/sysconfig/network-scripts/ifcfg-eth*X*** file. For example, if the FCoE device is eth2, then edit **/etc/sysconfig/network-scripts/ifcfg-eth2** accordingly.

3. Start the data center bridging daemon (**dcbd**) using the following command:

```
# /etc/init.d/lldpad start
```

4. For networking interfaces that implement a hardware DCBX client, skip this step and move on to the next.

   For interfaces that require a software DCBX client, enable data center bridging on the Ethernet interface using the following commands:

```
# dcbtool sc ethX dcb on
```

   Then, enable FCoE on the Ethernet interface by running:

```
# dcbtool sc ethX app:fcoe e:1
```

Note

These commands will only work if the **dcbd** settings for the Ethernet interface were not changed.

5. Load the FCoE device now using:

```
# ifconfig ethX up
```

6. Start FCoE using:

```
# service fcoe start
```

The FCoE device should appear shortly, assuming all other settings on the fabric are correct. To view configured FCoE devices, run:

```
# fcoeadm -i
```

After correctly configuring the Ethernet interface to use FCoE, Red Hat recommends that you set FCoE and **lldpad** to run at startup. To do so, use **chkconfig**, as in:

```
# chkconfig lldpad on
```

```
# chkconfig fcoe on
```

Warning

Do not run software-based DCB or LLDP on CNAs that implement DCB.

Some Combined Network Adapters (CNAs) implement the Data Center Bridging (DCB) protocol in firmware. The DCB protocol assumes that there is just one originator of DCB on a particular network link. This means that any higher-level software implementation of DCB, or Link Layer Discovery Protocol (LLDP), must be disabled on CNAs that implement DCB.

25.7.1. Fibre-Channel over Ethernet (FCoE) Target Set up

In addition to mounting LUNs over FCoE, as described in Section 25.7, “Configuring a Fibre-Channel Over Ethernet Interface”, exporting LUNs to other machines over FCoE is also supported.

Important

Before proceeding, refer to Section 25.7, “Configuring a Fibre-Channel Over Ethernet Interface” and verify that basic FCoE set up is completed, and that **fcoeadm -i** displays configured FCoE interfaces.

Procedure 25.5. Configure FCoE target

1. Setting up an FCoE target requires the installation of the **fcoe-target-utils** package, along with its dependencies.

```
# yum install fcoe-target-utils
```

2. FCoE target support is based on the LIO kernel target and does not require a userspace daemon. However, it is still necessary to enable the fcoe-target service to load the needed kernel modules and maintain the configuration across reboots.

```
# service fcoe-target start
```

```
# chkconfig fcoe-target on
```

3. Configuration of an FCoE target is performed using the **targetcli** utility, rather than by editing a **.conf** as may be expected. The settings are then saved so they may be restored if the system restarts.

```
# targetcli
```

targetcli is a hierarchical configuration shell. Moving between nodes in the shell uses **cd**, and **ls** shows the contents at or below the current configuration node. To get more options, the command **help** is also available.

4. Define the file, block device, or pass-through SCSI device to export as a backstore.

Example 25.5. Example 1 of defining a device

```
/> backstores/block create example1 /dev/sda4
```

This creates a backstore called **example1** that maps to the **/dev/sda4** block device.

Example 25.6. Example 2 of defining a device

```
/> backstores/fileio create example2 /srv/example2.img 100M
```

This creates a backstore called **example2** which maps to the given file. If the file does not exist, it will be created. File size may use K, M, or G abbreviations and is only needed when the backing file does not exist.

Note

If the global **auto_cd_after_create** option is on (the default), executing a create command will change the current configuration node to the newly created object. This can be disabled with **set global auto_cd_after_create=false**. Returning to the root node is possible with **cd /**.

5. Create an FCoE target instance on an FCoE interface.

```
/> tcm_fc/ create 00:11:22:33:44:55:66:77
```

If FCoE interfaces are present on the system, tab-completing after **create** will list available interfaces. If not, ensure **fcoeadm -i** shows active interfaces.

6. Map a backstore to the target instance.

Example 25.7. Example of mapping a backstore to the target instance

```
/> cd tcm_fc/00:11:22:33:44:55:66:77
```

```
/> luns/ create /backstores/fileio/example2
```

7. Allow access to the LUN from an FCoE initiator.

```
/> acls/ create 00:99:88:77:66:55:44:33
```

The LUN should now be accessible to that initiator.

8. Exit **targetcli** by typing **exit** or entering **ctrl**+**D**.

Exiting **targetcli** will save the configuration by default. However it may be explicitly saved with the **saveconfig** command.

Refer to the **targetcli** manpage for more information.

25.8. Configuring an FCoE Interface to Automatically Mount at Boot

Note

The instructions in this section are available in **/usr/share/doc/fcoe-utils-*version*/README** as of Red Hat Enterprise Linux 6.1. Refer to that document for any possible changes throughout minor releases.

You can mount newly discovered disks via **udev** rules, **autofs**, and other similar methods. Sometimes, however, a specific service might require the FCoE disk to be mounted at boot-time. In such cases, the FCoE disk should be mounted *as soon as* the **fcoe** service runs and *before* the initiation of any service that requires the FCoE disk.

To configure an FCoE disk to automatically mount at boot, add proper FCoE mounting code to the startup script for the **fcoe** service. The **fcoe** startup script is **/etc/init.d/fcoe**.

The FCoE mounting code is different per system configuration, whether you are using a simple formatted FCoE disk, LVM, or multipathed device node.

Example 25.8. FCoE mounting code

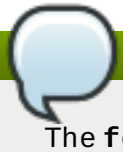
The following is a sample FCoE mounting code for mounting file systems specified via wild cards in **/etc/fstab**:

```
mount_fcoe_disks_from_fstab()
 {
     local timeout=20
     local done=1
     local fcoe_disks=($(egrep 'by-path\/fc-.*_netdev' /etc/fstab | cut
-d ' ' -f1))

     test -z $fcoe_disks && return 0

     echo -n "Waiting for fcoe disks . "
     while [ $timeout -gt 0 ]; do
  for disk in ${fcoe_disks[*]}; do
   if ! test -b $disk; then
    done=0
    break
   fi
  done

  test $done -eq 1 && break;
  sleep 1
  echo -n ". "
  done=1
  let timeout--
     done

     if test $timeout -eq 0; then
  echo "timeout!"
     else
  echo "done!"
     fi

     # mount any newly discovered disk
     mount -a 2>/dev/null
 }
```

The **mount_fcoe_disks_from_fstab** function should be invoked *after* the **fcoe** service script starts the **fcoemon** daemon. This will mount FCoE disks specified by the following paths in **/etc/fstab**:

```
/dev/disk/by-path/fc-0xXX:0xXX /mnt/fcoe-disk1 ext3  defaults,_netdev
0 0
/dev/disk/by-path/fc-0xYY:0xYY /mnt/fcoe-disk2 ext3  defaults,_netdev
0 0
```

Entries with **fc-** and **_netdev** sub-strings enable the **mount_fcoe_disks_from_fstab** function to identify FCoE disk mount entries. For more information on **/etc/fstab** entries, refer to **man 5 fstab**.



Note

The **fcoe** service does not implement a timeout for FCoE disk discovery. As such, the FCoE mounting code should implement its own timeout period.

25.9. Scanning Storage Interconnects

There are several commands available that allow you to reset and/or scan one or more interconnects, potentially adding and removing multiple devices in one operation. This type of scan can be disruptive, as it can cause delays while I/O operations timeout, and remove devices unexpectedly. As such, Red Hat recommends that this type of scan be used *only when necessary*. In addition, the following restrictions must be observed when scanning storage interconnects:

1. All I/O on the effected interconnects must be paused and flushed before executing the procedure, and the results of the scan checked before I/O is resumed.

2. As with removing a device, interconnect scanning is not recommended when the system is under memory pressure. To determine the level of memory pressure, run the command **vmstat 1 100**; interconnect scanning is not recommended if free memory is less than 5% of the total memory in more than 10 samples per 100. It is also not recommended if swapping is active (non-zero **si** and **so** columns in the **vmstat** output). The command **free** can also display the total memory.

The following commands can be used to scan storage interconnects.

echo "1" > /sys/class/fc_host/host/issue_lip

This operation performs a *Loop Initialization Protocol* (*LIP*) and then scans the interconnect and causes the SCSI layer to be updated to reflect the devices currently on the bus. A LIP is, essentially, a bus reset, and will cause device addition and removal. This procedure is necessary to configure a new SCSI target on a Fibre Channel interconnect.

Bear in mind that **issue_lip** is an asynchronous operation. The command may complete before the entire scan has completed. You must monitor **/var/log/messages** to determine when it is done.

The **lpfc**, **qla2xxx**, and **bnx2fc** drivers support **issue_lip**. For more information about the API capabilities supported by each driver in Red Hat Enterprise Linux, refer to Table 25.1, “Fibre-Channel API Capabilities”.

/usr/bin/rescan-scsi-bus.sh

This script was included as of Red Hat Enterprise Linux 5.4. By default, this script scans all the SCSI buses on the system, updating the SCSI layer to reflect new devices on the bus. The script provides additional options to allow device removal and the issuing of LIPs. For more information about this script (including known issues), refer to Section 25.15, “Adding/Removing a Logical Unit Through rescan-scsi-bus.sh”.

echo "- - -" > /sys/class/scsi_host/host*h*/scan

This is the same command described in Section 25.6, “Adding a Storage Device or Path” to add a storage device or path. In this case, however, the channel number, SCSI target ID, and LUN values are replaced by wildcards. Any combination of identifiers and wildcards is allowed, allowing you to make the command as specific or broad as needed. This procedure will add LUNs, but not remove them.

rmmod driver-name or **modprobe driver-name**

These commands completely re-initialize the state of all interconnects controlled by the driver. Although this is extreme, it may be appropriate in some situations. This may be used, for example, to re-start the driver with a different module parameter value.

25.10. iSCSI Discovery Configuration

The default iSCSI configuration file is **/etc/iscsi/iscsid.conf**. This file contains iSCSI settings used by **iscsid** and **iscsiadm**.

During target discovery, the **iscsiadm** tool uses the settings in **/etc/iscsi/iscsid.conf** to create two types of records:

Node records in /var/lib/iscsi/nodes

When logging into a target, **iscsiadm** uses the settings in this file.

Discovery records in /var/lib/iscsi/*discovery_type*

When performing discovery to the same destination, **iscsiadm** uses the settings in this file.

Before using different settings for discovery, delete the current discovery records (i.e. **/var/lib/iscsi/*discovery_type***) first. To do this, use the following command:

iscsiadm -m discovery -t *discovery_type* -p *target_IP*:*port* -o delete [7]

Here, ***discovery_type*** can be either **sendtargets**, **isns**, or **fw**.

For details on different types of discovery, refer to the *DISCOVERY TYPES* section of **man iscsiadm**.

There are two ways to reconfigure discovery record settings:

- Edit the **/etc/iscsi/iscsid.conf** file directly prior to performing a discovery. Discovery settings use the prefix **discovery**; to view them, run:

```
# iscsiadm -m discovery -t discovery_type -p target_IP:port
```

- Alternatively, **iscsiadm** can also be used to directly change discovery record settings, as in:

```
# iscsiadm -m discovery -t discovery_type -p target_IP:port -o update
-n setting -v %value
```

  Refer to **man iscsiadm** for more information on available ***setting***s and valid ***value***s for each.

After configuring discovery settings, any subsequent attempts to discover new targets will use the new settings. Refer to Section 25.12, “Scanning iSCSI Interconnects” for details on how to scan for new iSCSI targets.

For more information on configuring iSCSI target discovery, refer to the **man** pages of **iscsiadm** and **iscsid**. The **/etc/iscsi/iscsid.conf** file also contains examples on proper configuration syntax.

25.11. Configuring iSCSI Offload and Interface Binding

This chapter describes how to set up iSCSI interfaces in order to bind a session to a NIC port when using software iSCSI. It also describes how to set up interfaces for use with network devices that support offloading; namely, devices from Chelsio, Broadcom and ServerEngines.

The network subsystem can be configured to determine the path/NIC that iSCSI interfaces should use for binding. For example, if portals and NICs are set up on different subnets, then it is not necessary to manually configure iSCSI interfaces for binding.

Before attempting to configure an iSCSI interface for binding, run the following command first:

```
$ ping -I ethX target_IP
```

If **ping** fails, then you will not be able to bind a session to a NIC. If this is the case, check the network settings first.

25.11.1. Viewing Available iface Configurations

From Red Hat Enterprise Linux 5.5 iSCSI offload and interface binding is supported for the following iSCSI initiator implementations:

- *Software iSCSI* — like the **scsi_tcp** and **ib_iser** modules, this stack allocates an iSCSI host instance (i.e. **scsi_host**) per session, with a single connection per session. As a result, **/sys/class_scsi_host** and **/proc/scsi** will report a **scsi_host** for each connection/session you are logged into.
- *Offload iSCSI* — like the Chelsio **cxgb3i**, Broadcom **bnx2i** and ServerEngines **be2iscsi** modules, this stack allocates a **scsi_host** for each PCI device. As such, each port on a host bus adapter will show up as a different PCI device, with a different **scsi_host** per HBA port.

To manage both types of initiator implementations, **iscsiadm** uses the **iface** structure. With this structure, an **iface** configuration must be entered in **/var/lib/iscsi/ifaces** for each HBA port, software iSCSI, or network device (**ethX**) used to bind sessions.

To view available **iface** configurations, run **iscsiadm -m iface**. This will display **iface** information in the following format:

```
iface_name
transport_name,hardware_address,ip_address,net_ifacename,initiator_name
```

Refer to the following table for an explanation of each value/setting.

Table 25.2. iface Settings

Setting	Description
iface_name	**iface** configuration name.
transport_name	Name of driver
hardware_address	MAC address
ip_address	IP address to use for this port
net_iface_name	Name used for the **vlan** or alias binding of a software iSCSI session. For iSCSI offloads, **net_iface_name** will be **<empty>** because this value is not persistent across reboots.
initiator_name	This setting is used to override a default name for the initiator, which is defined in **/etc/iscsi/initiatorname.iscsi**

Example 25.9. Sample output of the iscsiadm -m iface command

The following is a sample output of the **iscsiadm -m iface** command:

```
iface0 qla4xxx,00:c0:dd:08:63:e8,20.15.0.7,default,iqn.2005-
06.com.redhat:madmax
iface1 qla4xxx,00:c0:dd:08:63:ea,20.15.0.9,default,iqn.2005-
06.com.redhat:madmax
```

For software iSCSI, each **iface** configuration must have a unique name (with less than 65 characters). The **iface_name** for network devices that support offloading appears in the format ***transport_name*.*hardware_name***.

Example 25.10. `iscsiadm -m iface` output with a Chelsio network card

For example, the sample output of **iscsiadm -m iface** on a system using a Chelsio network card might appear as:

```
default tcp,<empty>,<empty>,<empty>,<empty>
iser iser,<empty>,<empty>,<empty>,<empty>
cxgb3i.00:07:43:05:97:07 cxgb3i,00:07:43:05:97:07,<empty>,<empty>,
<empty>
```

It is also possible to display the settings of a specific **iface** configuration in a more friendly way. To do so, use the option **-I *iface_name***. This will display the settings in the following format:

```
iface.setting = value
```

Example 25.11. Using `iface` settings with a Chelsio converged network adapter

Using the previous example, the **iface** settings of the same Chelsio converged network adapter (i.e. **iscsiadm -m iface -I cxgb3i.00:07:43:05:97:07**) would appear as:

```
# BEGIN RECORD 2.0-871
iface.iscsi_ifacename = cxgb3i.00:07:43:05:97:07
iface.net_ifacename = <empty>
iface.ipaddress = <empty>
iface.hwaddress = 00:07:43:05:97:07
iface.transport_name = cxgb3i
iface.initiatorname = <empty>
# END RECORD
```

25.11.2. Configuring an iface for Software iSCSI

As mentioned earlier, an **iface** configuration is required for each network object that will be used to bind a session.

Before

To create an **iface** configuration for software iSCSI, run the following command:

```
# iscsiadm -m iface -I iface_name --op=new
```

This will create a new *empty* **iface** configuration with a specified ***iface_name***. If an existing **iface** configuration already has the same ***iface_name***, then it will be overwritten with a new, empty one.

To configure a specific setting of an **iface** configuration, use the following command:

```
# iscsiadm -m iface -I iface_name --op=update -n iface.setting -v
hw_address
```

Example 25.12. Set MAC address of iface0

For example, to set the MAC address (**hardware_address**) of **iface0** to **00:0F:1F:92:6B:BF**, run:

```
# iscsiadm -m iface -I iface0 --op=update -n iface.hwaddress -v
00:0F:1F:92:6B:BF
```

Warning

Do not use **default** or **iser** as **iface** names. Both strings are special values used by **iscsiadm** for backward compatibility. Any manually-created **iface** configurations named **default** or **iser** will disable backwards compatibility.

25.11.3. Configuring an iface for iSCSI Offload

By default, **iscsiadm** will create an **iface** configuration for each Chelsio, Broadcom, and ServerEngines port. To view available **iface** configurations, use the same command for doing so in software iSCSI, i.e. **iscsiadm -m iface**.

Before using the **iface** of a network card for iSCSI offload, first set the IP address (***target_IP***[7]) that the device should use. For ServerEngines devices that use the **be2iscsi** driver (i.e. ServerEngines iSCSI HBAs), the IP address is configured in the ServerEngines BIOS set up screen.

For Chelsio and Broadcom devices, the procedure for configuring the IP address is the same as for any other **iface** setting. So to configure the IP address of the **iface**, use:

```
# iscsiadm -m iface -I iface_name -o update -n iface.ipaddress -v
target_IP
```

Example 25.13. Set the iface IP address of a Chelsio card

For example, to set the **iface** IP address of a Chelsio card (with **iface** name **cxgb3i.00:07:43:05:97:07**) to **20.15.0.66**, use:

```
# iscsiadm -m iface -I cxgb3i.00:07:43:05:97:07 -o update -n
iface.ipaddress -v 20.15.0.66
```

25.11.4. Binding/Unbinding an iface to a Portal

Whenever **iscsiadm** is used to scan for interconnects, it will first check the **iface.transport** settings of each **iface** configuration in **/var/lib/iscsi/ifaces**. The **iscsiadm** utility will then bind discovered portals to any **iface** whose **iface.transport** is **tcp**.

This behavior was implemented for compatibility reasons. To override this, use the **-I *iface_name*** to specify which portal to bind to an **iface**, as in:

```
# iscsiadm -m discovery -t st -p target_IP:port -I iface_name -P 1
[7]
```

By default, the **iscsiadm** utility will not automatically bind any portals to **iface** configurations that use offloading. This is because such **iface** configurations will not have **iface.transport** set to **tcp**. As such, the **iface** configurations of Chelsio, Broadcom, and ServerEngines ports need to be manually bound to discovered portals.

It is also possible to prevent a portal from binding to any existing **iface**. To do so, use **default** as the ***iface_name***, as in:

```
# iscsiadm -m discovery -t st -p IP:port -I default -P 1
```

To remove the binding between a target and **iface**, use:

```
# iscsiadm -m node -targetname proper_target_name -I iface0 --op=delete
      [8]
```

To delete all bindings for a specific **iface**, use:

```
# iscsiadm -m node -I iface_name --op=delete
```

To delete bindings for a specific portal (e.g. for Equalogic targets), use:

```
# iscsiadm -m node -p IP:port -I iface_name --op=delete
```

Note

If there are no **iface** configurations defined in **/var/lib/iscsi/iface** and the **-I** option is not used, **iscsiadm** will allow the network subsystem to decide which device a specific portal should use.

25.12. Scanning iSCSI Interconnects

For iSCSI, if the targets send an iSCSI async event indicating new storage is added, then the scan is done automatically. Cisco MDS™ and EMC Celerra™ support this feature.

However, if the targets do not send an iSCSI async event, you need to manually scan them using the **iscsiadm** utility. Before doing so, however, you need to first retrieve the proper **--targetname** and the **--portal** values. If your device model supports only a single logical unit and portal per target, use **iscsiadm** to issue a **sendtargets** command to the host, as in:

```
# iscsiadm -m discovery -t sendtargets -p target_IP:port
[7]
```

The output will appear in the following format:

```
target_IP:port,target_portal_group_tag proper_target_name
```

Example 25.14. Using `iscsiadm` to issue a `sendtargets` command

For example, on a target with a ***proper_target_name*** of **iqn.1992-08.com.netapp:sn.33615311** and a ***target_IP:port*** of **10.15.85.19:3260**, the output may appear as:

```
10.15.84.19:3260,2 iqn.1992-08.com.netapp:sn.33615311
10.15.85.19:3260,3 iqn.1992-08.com.netapp:sn.33615311
```

In this example, the target has two portals, each using ***target_ip:port***s of **10.15.84.19:3260** and **10.15.85.19:3260**.

To see which **iface** configuration will be used for each session, add the **-P 1** option. This option will print also session information in tree format, as in:

```
    Target: proper_target_name
        Portal: target_IP:port,target_portal_group_tag
           Iface Name: iface_name
```

Example 25.15. View `iface` configuration

For example, with **iscsiadm -m discovery -t sendtargets -p 10.15.85.19:3260 -P 1**, the output may appear as:

```
Target: iqn.1992-08.com.netapp:sn.33615311
    Portal: 10.15.84.19:3260,2
       Iface Name: iface2
    Portal: 10.15.85.19:3260,3
       Iface Name: iface2
```

This means that the target **iqn.1992-08.com.netapp:sn.33615311** will use **iface2** as its **iface** configuration.

With some device models (e.g. from EMC and Netapp), however, a single target may have multiple logical units and/or portals. In this case, issue a **sendtargets** command to the host first to find new portals on the target. Then, rescan the existing sessions using:

```
# iscsiadm -m session --rescan
```

You can also rescan a specific session by specifying the session's ***SID*** value, as in:

```
# iscsiadm -m session -r SID --rescan
      [9]
```

If your device supports multiple targets, you will need to issue a **sendtargets** command to the hosts to find new portals for *each* target. Then, rescan existing sessions to discover new logical units on existing sessions (i.e. using the **--rescan** option).

Important

The **sendtargets** command used to retrieve **--targetname** and **--portal** values overwrites the contents of the **/var/lib/iscsi/nodes** database. This database will then be repopulated using the settings in **/etc/iscsi/iscsid.conf**. However, this will not occur if a session is currently logged in and in use.

To safely add new targets/portals or delete old ones, use the **-o new** or **-o delete** options, respectively. For example, to add new targets/portals without overwriting **/var/lib/iscsi/nodes**, use the following command:

```
iscsiadm -m discovery -t st -p target_IP -o new
```

To delete **/var/lib/iscsi/nodes** entries that the target did not display during discovery, use:

```
iscsiadm -m discovery -t st -p target_IP -o delete
```

You can also perform both tasks simultaneously, as in:

```
iscsiadm -m discovery -t st -p target_IP -o delete -o new
```

The **sendtargets** command will yield the following output:

```
ip:port,target_portal_group_tag proper_target_name
```

Example 25.16. Output of the sendtargets command

For example, given a device with a single target, logical unit, and portal, with **equallogic-iscsi1** as your ***target_name***, the output should appear similar to the following:

```
10.16.41.155:3260,0 iqn.2001-05.com.equallogic:6-8a0900-ac3fe0101-
63aff113e344a4a2-dl585-03-1
```

Note that ***proper_target_name*** and ***ip:port,target_portal_group_tag*** are identical to the values of the same name in Section 25.2.1, “iSCSI API”.

At this point, you now have the proper **--targetname** and **--portal** values needed to manually scan for iSCSI devices. To do so, run the following command:

```
# iscsiadm --mode node --targetname proper_target_name --portal
ip:port,target_portal_group_tag \ --login

      [10]
```

Example 25.17. Full `iscsiadm` command

Using our previous example (where ***proper_target_name*** is **equallogic-iscsi1**), the full command would be:

```
# iscsiadm --mode node --targetname  \ iqn.2001-05.com.equallogic:6-
8a0900-ac3fe0101-63aff113e344a4a2-dl585-03-1  \ --portal
10.16.41.155:3260,0 --login[10]
```

25.13. Logging in to an iSCSI Target

As mentioned in Section 25.2, “iSCSI”, the iSCSI service must be running in order to discover or log into targets. To start the iSCSI service, run:

```
# service iscsi start
```

When this command is executed, the iSCSI **init** scripts will automatically log into targets where the **node.startup** setting is configured as **automatic**. This is the default value of **node.startup** for all targets.

To prevent automatic login to a target, set **node.startup** to **manual**. To do this, run the following command:

```
# iscsiadm -m node --targetname proper_target_name -p target_IP:port -o
update -n node.startup -v manual
```

Deleting the entire record will also prevent automatic login. To do this, run:

```
# iscsiadm -m node --targetname proper_target_name -p target_IP:port -o
delete
```

To automatically mount a file system from an iSCSI device on the network, add a partition entry for the mount in **/etc/fstab** with the **_netdev** option. For example, to automatically mount the iSCSI device **sdb** to **/mount/iscsi** during startup, add the following line to **/etc/fstab**:

```
/dev/sdb /mnt/iscsi ext3 _netdev 0 0
```

To manually log in to an iSCSI target, use the following command:

```
# iscsiadm -m node --targetname proper_target_name -p target_IP:port -l
```

Note

The ***proper_target_name*** and ***target_IP:port*** refer to the full name and IP address/port combination of a target. For more information, refer to Section 25.2.1, “iSCSI API” and Section 25.12, “Scanning iSCSI Interconnects”.

25.14. Resizing an Online Logical Unit

In most cases, fully resizing an online *logical unit* involves two things: resizing the logical unit itself and reflecting the size change in the corresponding multipath device (if multipathing is enabled on the system).

To resize the online logical unit, start by modifying the logical unit size through the array management interface of your storage device. This procedure differs with each array; as such, consult your storage array vendor documentation for more information on this.

Note

In order to resize an online file system, the file system must not reside on a partitioned device.

25.14.1. Resizing Fibre Channel Logical Units

After modifying the online logical unit size, re-scan the logical unit to ensure that the system detects the updated size. To do this for Fibre Channel logical units, use the following command:

```
$ echo 1 > /sys/block/sdX/device/rescan
```

Important

To re-scan fibre channel logical units on a system that uses multipathing, execute the aforementioned command for each sd device (i.e. **sd1**, **sd2**, and so on) that represents a path for the multipathed logical unit. To determine which devices are paths for a multipath logical unit, use **multipath -ll**; then, find the entry that matches the logical unit being resized. It is advisable that you refer to the WWID of each entry to make it easier to find which one matches the logical unit being resized.

25.14.2. Resizing an iSCSI Logical Unit

After modifying the online logical unit size, re-scan the logical unit to ensure that the system detects the updated size. To do this for iSCSI devices, use the following command:

```
# iscsiadm -m node --targetname target_name -R
[7]
```

Replace ***target_name*** with the name of the target where the device is located.

Note

You can also re-scan iSCSI logical units using the following command:

```
# iscsiadm -m node -R -I interface
```

Replace ***interface*** with the corresponding interface name of the resized logical unit (for example, **iface0**). This command performs two operations:

- It scans for new devices in the same way that the command **echo "- - -" > /sys/class/scsi_host/*host*/scan** does (refer to Section 25.12, "Scanning iSCSI Interconnects").
- It re-scans for new/modified logical units the same way that the command **echo 1 > /sys/block/sdX/device/rescan** does. Note that this command is the same one used for re-scanning fibre-channel logical units.

25.14.3. Updating the Size of Your Multipath Device

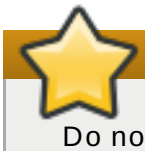
If multipathing is enabled on your system, you will also need to reflect the change in logical unit size to the logical unit's corresponding multipath device (*after* resizing the logical unit). For Red Hat Enterprise Linux 5.3 (or later), you can do this through **multipathd**. To do so, first ensure that **multipathd** is running using **service multipathd status**. Once you've verified that **multipathd** is operational, run the following command:

```
# multipathd -k"resize map multipath_device"
```

The ***multipath_device*** variable is the corresponding multipath entry of your device in **/dev/mapper**. Depending on how multipathing is set up on your system, ***multipath_device*** can be either of two formats:

- **mpath*X***, where ***X*** is the corresponding entry of your device (for example, **mpath0**)
- a WWID; for example, **3600508b400105e21000090000000490000**

To determine which multipath entry corresponds to your resized logical unit, run **multipath -ll**. This displays a list of all existing multipath entries in the system, along with the major and minor numbers of their corresponding devices.



Important

Do not use **multipathd -k"resize map *multipath_device*"** if there are any commands queued to ***multipath_device***. That is, do not use this command when the **no_path_retry** parameter (in **/etc/multipath.conf**) is set to **"queue"**, and there are no active paths to the device.

If your system is using Red Hat Enterprise Linux 5.0-5.2, you will need to perform the following procedure to instruct the **multipathd** daemon to recognize (and adjust to) the changes you made to the resized logical unit:

Procedure 25.6. Resizing the Corresponding Multipath Device (Required for Red Hat Enterprise Linux 5.0 - 5.2)

1. Dump the device mapper table for the multipathed device using:

   dmsetup table *multipath_device*

2. Save the dumped device mapper table as ***table_name***. This table will be re-loaded and edited later.

3. Examine the device mapper table. Note that the first two numbers in each line correspond to the start and end sectors of the disk, respectively.

4. Suspend the device mapper target:

   dmsetup suspend *multipath_device*

5. Open the device mapper table you saved earlier (i.e. ***table_name***). Change the second number (i.e. the disk end sector) to reflect the new number of 512 byte sectors in the disk. For example, if the new disk size is 2GB, change the second number to 4194304.

6. Reload the modified device mapper table:

   dmsetup reload *multipath_device table_name*

7. Resume the device mapper target:

   dmsetup resume *multipath_device*

For more information about multipathing, refer to the *Red Hat Enterprise Linux 6 DM Multipath* guide.

25.14.4. Changing the Read/Write State of an Online Logical Unit

Certain storage devices provide the user with the ability to change the state of the device from Read/Write (R/W) to Read-Only (RO), and from RO to R/W. This is typically done through a management interface on the storage device. The operating system will not automatically update its view of the state of the device when a change is made. Follow the procedures described in this chapter to make the operating system aware of the change.

Run the following command, replacing XYZ with the desired device designator, to determine the operating system's current view of the R/W state of a device:

```
# blockdev --getro /dev/sdXYZ
```

The following command is also available for Red Hat Enterprise Linux 6:

```
# cat /sys/block/sdXYZ/ro 1 = read-only 0 = read-write
```

When using multipath, refer to the *ro* or *rw* field in the second line of output from the **multipath -ll** command. For example:

```
36001438005deb4710000500000640000 dm-8 GZ,GZ500
[size=20G][features=0][hwhandler=0][ro]
\_ round-robin 0 [prio=200][active]
 \_ 6:0:4:1  sdax 67:16  [active][ready]
 \_ 6:0:5:1  sday 67:32  [active][ready]
\_ round-robin 0 [prio=40][enabled]
 \_ 6:0:6:1  sdaz 67:48  [active][ready]
 \_ 6:0:7:1  sdba 67:64  [active][ready]
```

To change the R/W state, use the following procedure:

Procedure 25.7. Change the R/W state

1. To move the device from RO to R/W, see step 2.

   To move the device from R/W to RO, ensure no further writes will be issued. Do this by stopping the application, or through the use of an appropriate, application-specific action.

   Ensure that all outstanding write I/Os are complete with the following command:

   ```
   # blockdev --flushbufs /dev/device
   ```

   Replace *device* with the desired designator; for a device mapper multipath, this is the entry for your device in **dev/mapper**. For example, **/dev/mapper/*mpath3***.

2. Use the management interface of the storage device to change the state of the logical unit from R/W to RO, or from RO to R/W. The procedure for this differs with each array. Consult applicable storage array vendor documentation for more information.

3. Perform a re-scan of the device to update the operating system's view of the R/W state of the device. If using a device mapper multipath, perform this re-scan for each path to the device before issuing the command telling multipath to reload its device maps.

   This process is explained in further detail in Section 25.14.4.1, “Rescanning logical units”.

25.14.4.1. Rescanning logical units

After modifying the online logical unit Read/Write state, as described in Section 25.14.4, “Changing the Read/Write State of an Online Logical Unit”, re-scan the logical unit to ensure the system detects the updated state with the following command:

```
# echo 1 > /sys/block/sdX/device/rescan
```

To re-scan logical units on a system that uses multipathing, execute the above command for each sd device that represents a path for the multipathed logical unit. For example, run the command on sd1, sd2 and all other sd devices. To determine which devices are paths for a multipath unit, use **multipath -11**, then find the entry that matches the logical unit to be changed.

Example 25.18. Use of the multipath -11 command

For example, the **multipath -11** above shows the path for the LUN with WWID 36001438005deb4710000500000640000. In this case, enter:

```
# echo 1 > /sys/block/sdax/device/rescan
# echo 1 > /sys/block/sday/device/rescan
# echo 1 > /sys/block/sdaz/device/rescan
# echo 1 > /sys/block/sdba/device/rescan
```

25.14.4.2. Updating the R/W state of a multipath device

If multipathing is enabled, after rescanning the logical unit, the change in its state will need to be reflected in the logical unit's corresponding multipath drive. Do this by reloading the multipath device maps with the following command:

```
# multipath -r
```

The **multipath -11** command can then be used to confirm the change.

25.14.4.3. Documentation

Further information can be found in the Red Hat Knowledgebase. To access this, navigate to https://www.redhat.com/wapps/sso/login.html?redirect=https://access.redhat.com/knowledge/ and log in. Then access the article at https://access.redhat.com/kb/docs/DOC-32850.

25.15. Adding/Removing a Logical Unit Through rescan-scsi-bus.sh

The **sg3_utils** package provides the **rescan-scsi-bus.sh** script, which can automatically update the logical unit configuration of the host as needed (after a device has been added to the system). The **rescan-scsi-bus.sh** script can also perform an **issue_lip** on supported devices. For more information about how to use this script, refer to **rescan-scsi-bus.sh --help**.

To install the **sg3_utils** package, run **yum install sg3_utils**.

Known Issues With rescan-scsi-bus.sh

When using the **rescan-scsi-bus.sh** script, take note of the following known issues:

- In order for **rescan-scsi-bus.sh** to work properly, **LUN0** must be the first mapped logical unit. The **rescan-scsi-bus.sh** can only detect the first mapped logical unit if it is **LUN0**. The **rescan-scsi-bus.sh** will not be able to scan any other logical unit unless it detects the first mapped logical unit even if you use the **--nooptscan** option.
- A race condition requires that **rescan-scsi-bus.sh** be run twice if logical units are mapped for the first time. During the first scan, **rescan-scsi-bus.sh** only adds **LUN0**; all other logical units are added in the second scan.
- A bug in the **rescan-scsi-bus.sh** script incorrectly executes the functionality for recognizing a change in logical unit size when the **--remove** option is used.
- The **rescan-scsi-bus.sh** script does not recognize ISCSI logical unit removals.

25.16. Modifying Link Loss Behavior

This section describes how to modify the link loss behavior of devices that use either fibre channel or iSCSI protocols.

25.16.1. Fibre Channel

If a driver implements the Transport **dev_loss_tmo** callback, access attempts to a device through a link will be blocked when a transport problem is detected. To verify if a device is blocked, run the following command:

```
$ cat /sys/block/device/device/state
```

This command will return **blocked** if the device is blocked. If the device is operating normally, this command will return **running**.

Procedure 25.8. Determining The State of a Remote Port

1. To determine the state of a remote port, run the following command:

```
$ cat
/sys/class/fc_remote_port/rport-H:B:R/port_state
```

2. This command will return **Blocked** when the remote port (along with devices accessed through it) are blocked. If the remote port is operating normally, the command will return **Online**.

3. If the problem is not resolved within **dev_loss_tmo** seconds, the rport and devices will be unblocked and all I/O running on that device (along with any new I/O sent to that device) will be failed.

Procedure 25.9. Changing dev_loss_tmo

- To change the **dev_loss_tmo** value, **echo** in the desired value to the file. For example, to set **dev_loss_tmo** to 30 seconds, run:

```
$ echo 30 >
/sys/class/fc_remote_port/rport-H:B:R/dev_loss_tmo
```

For more information about **dev_loss_tmo**, refer to Section 25.1.1, “Fibre Channel API”.

When a link or target port loss exceeds **dev_loss_tmo**, the **scsi_device** and **sd*N*** devices are removed. The target port SCSI ID binding is saved. When the target returns, the SCSI address and **sd*N***assignments may be changed. The SCSI address will change if there has been any LUN configuration changes behind the target port. The **sd*N*** names may change depending on timing variations during the LUN discovery process or due to LUN configuration change within storage. These assignments are not persistent as described in Section 25.3, “Persistent Naming”. Refer to section Section 25.3, “Persistent Naming” for alternative device naming methods that are persistent.

25.16.2. iSCSI Settings With dm-multipath

If **dm-multipath** is implemented, it is advisable to set iSCSI timers to immediately defer commands to the multipath layer. To configure this, nest the following line under **device {** in **/etc/multipath.conf**:

```
features  "1 queue_if_no_path"
```

This ensures that I/O errors are retried and queued if all paths are failed in the **dm-multipath** layer.

You may need to adjust iSCSI timers further to better monitor your SAN for problems. Available iSCSI timers you can configure are *NOP-Out Interval/Timeouts* and **replacement_timeout**, which are discussed in the following sections.

25.16.2.1. NOP-Out Interval/Timeout

To help monitor problems the SAN, the iSCSI layer sends a NOP-Out request to each target. If a NOP-Out request times out, the iSCSI layer responds by failing any running commands and instructing the SCSI layer to requeue those commands when possible.

When **dm-multipath** is being used, the SCSI layer will fail those running commands and defer them to the multipath layer. The multipath layer then retries those commands on another path. If **dm-multipath** is *not* being used, those commands are retried five times before failing altogether.

Intervals between NOP-Out requests are 10 seconds by default. To adjust this, open **/etc/iscsi/iscsid.conf** and edit the following line:

```
node.conn[0].timeo.noop_out_interval = [interval value]
```

Once set, the iSCSI layer will send a NOP-Out request to each target every *[interval value]* seconds.

By default, NOP-Out requests time out in 10 seconds [11]. To adjust this, open **/etc/iscsi/iscsid.conf** and edit the following line:

```
node.conn[0].timeo.noop_out_timeout = [timeout value]
```

This sets the iSCSI layer to timeout a NOP-Out request after *[timeout value]* seconds.

SCSI Error Handler

If the SCSI Error Handler is running, running commands on a path will not be failed immediately when a NOP-Out request times out on that path. Instead, those commands will be failed *after* **replacement_timeout** seconds. For more information about **replacement_timeout**, refer to Section 25.16.2.2, "**replacement_timeout**".

To verify if the SCSI Error Handler is running, run:

```
# iscsiadm -m session -P 3
```

25.16.2.2. replacement_timeout

replacement_timeout controls how long the iSCSI layer should wait for a timed-out path/session to reestablish itself before failing any commands on it. The default **replacement_timeout** value is 120 seconds.

To adjust **replacement_timeout**, open **/etc/iscsi/iscsid.conf** and edit the following line:

```
node.session.timeo.replacement_timeout = [replacement_timeout]
```

The **1 queue_if_no_path** option in **/etc/multipath.conf** sets iSCSI timers to immediately defer commands to the multipath layer (refer to Section 25.16.2, "iSCSI Settings With **dm-multipath**"). This setting prevents I/O errors from propagating to the application; because of this, you can set **replacement_timeout** to 15-20 seconds.

By configuring a lower **replacement_timeout**, I/O is quickly sent to a new path and executed (in the event of a NOP-Out timeout) while the iSCSI layer attempts to re-establish the failed path/session. If all paths time out, then the multipath and device mapper layer will internally queue I/O based on the settings in **/etc/multipath.conf** instead of **/etc/iscsi/iscsid.conf**.

Important

Whether your considerations are failover speed or security, the recommended value for **replacement_timeout** will depend on other factors. These factors include the network, target, and system workload. As such, it is recommended that you thoroughly test any new configurations to **replacements_timeout** before applying it to a mission-critical system.

25.16.3. iSCSI Root

When accessing the root partition directly through an iSCSI disk, the iSCSI timers should be set so that iSCSI layer has several chances to try to reestablish a path/session. In addition, commands should not be quickly re-queued to the SCSI layer. This is the opposite of what should be done when **dm-multipath** is implemented.

To start with, NOP-Outs should be disabled. You can do this by setting both NOP-Out interval and timeout to zero. To set this, open **/etc/iscsi/iscsid.conf** and edit as follows:

```
node.conn[0].timeo.noop_out_interval = 0
node.conn[0].timeo.noop_out_timeout = 0
```

In line with this, **replacement_timeout** should be set to a high number. This will instruct the system to wait a long time for a path/session to reestablish itself. To adjust **replacement_timeout**, open **/etc/iscsi/iscsid.conf** and edit the following line:

```
node.session.timeo.replacement_timeout = replacement_timeout
```

After configuring **/etc/iscsi/iscsid.conf**, you must perform a re-discovery of the affected storage. This will allow the system to load and use any new values in **/etc/iscsi/iscsid.conf**. For more information on how to discover iSCSI devices, refer to Section 25.12, “Scanning iSCSI Interconnects”.

Configuring Timeouts for a Specific Session

You can also configure timeouts for a specific session and make them non-persistent (instead of using **/etc/iscsi/iscsid.conf**). To do so, run the following command (replace the variables accordingly):

```
# iscsiadm -m node -T target_name -p target_IP:port -o update -n
node.session.timeo.replacement_timeout -v $timeout_value
```

Important

The configuration described here is recommended for iSCSI sessions involving root partition access. For iSCSI sessions involving access to other types of storage (namely, in systems that use **dm-multipath**), refer to Section 25.16.2, “iSCSI Settings With **dm-multipath**”.

25.17. Controlling the SCSI Command Timer and Device Status

The Linux SCSI layer sets a timer on each command. When this timer expires, the SCSI layer will quiesce the *host bus adapter* (HBA) and wait for all outstanding commands to either time out or complete. Afterwards, the SCSI layer will activate the driver's error handler.

When the error handler is triggered, it attempts the following operations in order (until one successfully executes):

1. Abort the command.
2. Reset the device.
3. Reset the bus.
4. Reset the host.

If all of these operations fail, the device will be set to the **offline** state. When this occurs, all I/O to that device will be failed, until the problem is corrected and the user sets the device to **running**.

The process is different, however, if a device uses the fibre channel protocol and the **rport** is blocked. In such cases, the drivers wait for several seconds for the **rport** to become online again before activating the error handler. This prevents devices from becoming offline due to temporary transport problems.

Device States

To display the state of a device, use:

```
$ cat /sys/block/device-name/device/state
```

To set a device to **running** state, use:

```
$ echo running > /sys/block/device-name/device/state
```

Command Timer

To control the command timer, you can write to **/sys/block/*device-name*/device/timeout**. To do so, run:

echo *value* /sys/block/*device-name*/device/timeout

Here, ***value*** is the timeout value (in seconds) you want to implement.

25.18. Online Storage Configuration Troubleshooting

This section provides solution to common problems users experience during online storage reconfiguration.

Logical unit removal status is not reflected on the host.

When a logical unit is deleted on a configured filer, the change is not reflected on the host. In such cases, **lvm** commands will hang indefinitely when **dm-multipath** is used, as the logical unit has now become *stale*.

To work around this, perform the following procedure:

Procedure 25.10. Working Around Stale Logical Units

1. Determine which **mpath** link entries in **/etc/lvm/cache/.cache** are specific to the stale logical unit. To do this, run the following command:

```
$ ls -l /dev/mpath | grep stale-logical-unit
```

Example 25.19. Determine specific mpath link entries

For example, if ***stale-logical-unit*** is 3600d0230003414f30000203a7bc41a00, the following results may appear:

```
lrwxrwxrwx 1 root root 7 Aug  2 10:33
/3600d0230003414f30000203a7bc41a00 -> ../dm-4
lrwxrwxrwx 1 root root 7 Aug  2 10:33
/3600d0230003414f30000203a7bc41a00p1 -> ../dm-5
```

This means that 3600d0230003414f30000203a7bc41a00 is mapped to two **mpath** links: **dm-4** and **dm-5**.

2. Next, open **/etc/lvm/cache/.cache**. Delete all lines containing ***stale-logical-unit*** and the **mpath** links that ***stale-logical-unit*** maps to.

Example 25.20. Delete relevant lines

Using the same example in the previous step, the lines you need to delete are:

```
/dev/dm-4
/dev/dm-5
/dev/mapper/3600d0230003414f30000203a7bc41a00
/dev/mapper/3600d0230003414f30000203a7bc41a00p1
/dev/mpath/3600d0230003414f30000203a7bc41a00
/dev/mpath/3600d0230003414f30000203a7bc41a00p1
```

[7] The ***target_IP*** and ***port*** variables refer to the IP address and port combination of a target/portal, respectively. For more information, refer to Section 25.2.1, “iSCSI API” and Section 25.12, “Scanning iSCSI Interconnects”.

[8] Refer to Section 25.12, “Scanning iSCSI Interconnects” for information on ***proper_target_name***.

[9] For information on how to retrieve a session's SID value, refer to Section 25.2.1, “iSCSI API”.

[10] This is a single command split into multiple lines, to accommodate printed and PDF versions of this document. All concatenated lines — preceded by the backslash (\) — should be treated as one command, sans backslashes.

[11] Prior to Red Hat Enterprise Linux 5.4, the default NOP-Out requests time out was 15 seconds.

Chapter 26. Device Mapper Multipathing and Virtual Storage

Red Hat Enterprise Linux 6 also supports *DM-Multipath* and *virtual storage*. Both features are documented in detail in the Red Hat books *DM Multipath* and *Virtualization Administration Guide*.

26.1. Virtual Storage

Red Hat Enterprise Linux 6 supports the following file systems/online storage methods for virtual storage:

- Fibre Channel
- iSCSI
- NFS
- GFS2

Virtualization in Red Hat Enterprise Linux 6 uses **`libvirt`** to manage virtual instances. The **`libvirt`** utility uses the concept of *storage pools* to manage storage for virtualized guests. A storage pool is storage that can be divided up into smaller volumes or allocated directly to a guest. Volumes of a storage pool can be allocated to virtualized guests. There are two categories of storage pools available:

Local storage pools

Local storage covers storage devices, files or directories directly attached to a host. Local storage includes local directories, directly attached disks, and LVM Volume Groups.

Networked (shared) storage pools

Networked storage covers storage devices shared over a network using standard protocols. It includes shared storage devices using Fibre Channel, iSCSI, NFS, GFS2, and SCSI RDMA protocols, and is a requirement for migrating guest virtualized guests between hosts.

Important

For comprehensive information on the deployment and configuration of virtual storage instances in your environment, refer to the *Virtualization Storage* section of the *Virtualization* guide provided by Red Hat.

26.2. DM-Multipath

Device Mapper Multipathing (DM-Multipath) is a feature that allows you to configure multiple I/O paths between server nodes and storage arrays into a single device. These I/O paths are physical SAN connections that can include separate cables, switches, and controllers. Multipathing aggregates the I/O paths, creating a new device that consists of the aggregated paths.

DM-Multipath are used primarily for the following reasons:

Redundancy

DM-Multipath can provide failover in an active/passive configuration. In an active/passive configuration, only half the paths are used at any time for I/O. If any element of an I/O path

(the cable, switch, or controller) fails, DM-Multipath switches to an alternate path.

Improved Performance

DM-Multipath can be configured in active/active mode, where I/O is spread over the paths in a round-robin fashion. In some configurations, DM-Multipath can detect loading on the I/O paths and dynamically re-balance the load.

Important

For comprehensive information on the deployment and configuration of DM-Multipath in your environment, refer to the *Using DM-Multipath* guide provided by Red Hat.

Revision History

Revision 2-52 **Wed Mar 25 2015** **Jacquelynn East**
Added ext back up and restore chapters

Revision 2-51 **Thu Oct 9 2014** **Jacquelynn East**
Version for 6.6 GA release

Revision 2-49 **Wed Jul 23 2014** **Jacquelynn East**
Corrected typographical errors BZ#1044526

Revision 2-48 **Wed Jul 23 2014** **Jacquelynn East**
Added note about **`--child-timeout`** option when using the hal daemon BZ#737755

Revision 2-47 **Thu May 29 2014** **Jacquelynn East**
Removed old note and added new note regarding disabling write barriers BZ#1095630

Revision 2-46 **Thu May 29 2014** **Jacquelynn East**
Added an extra step to creating a swapfile BZ#1104150

Revision 2-45 **Thu May 29 2014** **Jacquelynn East**
Reworded a paragraph in the persistent naming section BZ#1095007

Revision 2-44 **Mon May 26 2014** **Jacquelynn East**
Reworded a number of titles BZ#1099300
Fixed typographical error in autofs BZ#1084693
Removed a sentence from Common NFS Mount Options and added a note BZ#1069643
Added an important note to the fsck section BZ#1031864

Revision 2-41 **Thu May 22 2014** **Jacquelynn East**
Reworded NFS section in ACLs BZ#1028811

Revision 2-40 **Tue May 20 2014** **Jacquelynn East**
Clarified that a reference to the *Installation Guide* meant it was one of Red Hat's documents. BZ#1035061
Reworded a sentence in NFS section. BZ#1062733
Reworded a sentence in the /var section. BZ#1035058

Revision 2-38 **Mon Nov 18 2013** **Jacquelynn East**
Build for 6.5 GA

Revision 2-37 **Mon Nov 11 2013** **Jacquelynn East**
Several minor edits BZ#1028179.
Several minor edits BZ#1028195.
Several minor edits BZ#1028198.
Several minor edits BZ#1028200.
Several minor edits BZ#1028204.

Revision 2-36 **Tue Sep 24 2013** **Jacquelynn East**
Minor edits BZ#977871, BZ#904902.

Revision 2-35 **Thu Sep 05 2013** **Jacquelynn East**

Added fsck section BZ#904902.

Revision 2-27 **Thu Sep 05 2013** **Jacquelynn East**

Edited Chapter 9: Network File System (NFS).

Revision 2-26 **Mon Sep 02 2013** **Jacquelynn East**

Edited Chapter 5: The Ext3 File System; Chapter 6: The Ext4 File System; Chapter 7: Global File System 2; Chapter 8: The XFS File System.

Revision 2-25 **Thu Aug 22 2013** **Jacquelynn East**

Edited Chapter 1: Overview, Chapter 2: File System Structure and Maintenance, Chapter 3: Encrypte File System, and Chapter 4: Btrfs.

Revision 2-24 **Tue Aug 20 2013** **Jacquelynn East**

Edited and corrected Setting Cache Cull Limits section BZ#839106

Revision 2-22 **Fri Aug 2 2013** **Jacquelynn East**

Added paragraph detailing max capacity partitions BZ#857082

Revision 2-18 **Thu Aug 1 2013** **Jacquelynn East**

Clarified paragraph describing dev_loss_tmo BZ#913269
Clarified a sentence in LVM BZ#984339
Incorrect markup corrected in LVM BZ#984334
Sentences rephrased in LVM BZ#984335 BZ#984336

Revision 2-17 **Mon Jul 29 2013** **Jacquelynn East**

Removed polite "please" text BZ#984338

Revision 2-15 **Fri Jul 26 2013** **Jacquelynn East**

Added reference to a knowledge base article BZ#890453.
Fixed install file name BZ#888434
Fixed typo BZ#917054
Added bfa support for Host issue_lip BZ#852880

Revision 2-14 **Mon Mar 18 2013** **Jacquelynn East**

Corrected a dracut command BZ#885629.
Updated discard support BZ#977871

Revision 2-12 **Mon Mar 18 2013** **Jacquelynn East**

Reworded section in pNFS for clarity BZ#922125.

Revision 2-11 **Mon Feb 18 2013** **Jacquelynn East**

Version for 6.4 GA release.

Revision 2-10 **Mon Feb 18 2013** **Jacquelynn East**

BZ#894891 Updated pNFS section.

Revision 2-6 **Wed Jan 16 2013** **Jacquelynn East**

BZ#894891 Edited pNFS chapter to reflect 6.4 release notes.
BZ#804784 Removed section on remove_on_dev_loss.

Revision 2-5 **Tue Jan 15 2013** **Jacquelynn East**

BZ#894697 Updated sections regarding FCoE.

Revision 2-4 **Mon Jan 14 2013** **Jacquelynn East**

BZ#894891 As pNFS is coming out of tech preview status, all references to this were removed.

Revision 2-3 **Fri Oct 19 2012** **Jacquelynn East**

BZ#846498 Copy section from Performance Tuning Guide to File System Structure.

Revision 2-1 **Fri Oct 19 2012** **Jacquelynn East**

Branched for 6.4 Beta.
Created new edition based on significant structual reordering.

Revision 1-56 **Fri Oct 12 2012** **Jacquelynn East**

Added information to the overview and respective parts.

Revision 1-53 **Thu Oct 11 2012** **Jacquelynn East**

Rearranged and separated chapters into parts.

Revision 1-52 **Tue Oct 2 2012** **Jacquelynn East**

BZ#784335 Copied chapters across from Online Storage Guide.

Revision 1-50 **Tue Sep 25 2012** **Jacquelynn East**

BZ#804784 Removed warning regarding remove_on_dev_loss.

Revision 1-49 **Tue SEP 18 2012** **Jacquelynn East**

Added information BZ#784405.

Revision 1-48 **Thu Sep 13 2012** **Jacquelynn East**

Minor edit BZ#802859.
Section on using NFS over UDP removed BZ#845601.

Revision 1-47 **Wed Sep 5 2012** **Jacquelynn East**

Minor edits BZ#839102.

Revision 1-45 **Mon Jun 18 2012** **Jacquelynn East**

Version for 6.3 release.

Index

Symbols

/boot/ directory, The /boot/ Directory

/dev/disk
- persistent naming, Persistent Naming

/dev/shm , Gathering File System Information

/etc/fstab, Converting to an Ext3 File System, Mounting NFS File Systems using /etc/fstab, Mounting a File System

/etc/fstab file

- enabling disk quotas with, Enabling Quotas

/local/directory (client configuration, mounting)
- NFS, NFS Client Configuration

/proc
- /proc/devices, The /proc Virtual File System
- /proc/filesystems, The /proc Virtual File System
- /proc/mdstat, The /proc Virtual File System
- /proc/mounts, The /proc Virtual File System
- /proc/mounts/, The /proc Virtual File System
- /proc/partitions, The /proc Virtual File System

/proc/devices
- virtual file system (/proc), The /proc Virtual File System

/proc/filesystems
- virtual file system (/proc), The /proc Virtual File System

/proc/mdstat
- virtual file system (/proc), The /proc Virtual File System

/proc/mounts
- virtual file system (/proc), The /proc Virtual File System

/proc/mounts/
- virtual file system (/proc), The /proc Virtual File System

/proc/partitions
- virtual file system (/proc), The /proc Virtual File System

/remote/export (client configuration, mounting)
- NFS, NFS Client Configuration

A

Access Control Lists (see ACLs)

ACLs
- access ACLs, Setting Access ACLs
- additional resources, ACL References
- archiving with, Archiving File Systems With ACLs
- default ACLs, Setting Default ACLs
- getfacl , Retrieving ACLs
- mounting file systems with, Mounting File Systems
- mounting NFS shares with, NFS
- on ext3 file systems, Access Control Lists
- retrieving, Retrieving ACLs
- setfacl , Setting Access ACLs
- setting
  - access ACLs, Setting Access ACLs
- with Samba, Access Control Lists

adding a new volume group
- LVM, Adding a New Volume Group

adding paths to a storage device, Adding a Storage Device or Path

adding/removing
- LUN (logical unit number), Adding/Removing a Logical Unit Through rescan-scsi-bus.sh

advanced path
- storage considerations during installation, Updates to Storage Configuration During Installation

advanced RAID device creation
- RAID, Advanced RAID Device Creation

allocation features
- ext4, The Ext4 File System
- XFS, The XFS File System

Anaconda support
- RAID, RAID Support in the Installer

API, fibre channel, Fibre Channel API

API, iSCSI, iSCSI API

ATA standards
- I/O alignment and size, ATA

auto-partitioning and /home
- storage considerations during installation, Updates to Storage Configuration During Installation

autofs , autofs, autofs Configuration
- (see also NFS)

autofs version 5
- NFS, Improvements in autofs Version 5 over Version 4

B

backup/restoration
- XFS, Backup and Restoration of XFS File Systems

basic path
- storage considerations during installation, Updates to Storage Configuration During Installation

battery-backed write caches
- write barriers, Battery-Backed Write Caches

bcull (cache cull limits settings)
- FS-Cache, Setting Cache Cull Limits

binding/unbinding an iface to a portal
- offload and interface binding
  - iSCSI, Binding/Unbinding an iface to a Portal

block device ioctls (userspace access)

- I/O alignment and size, Block Device ioctls

blocked device, verifying
- fibre channel
  - modifying link loss behavior, Fibre Channel

brun (cache cull limits settings)
- FS-Cache, Setting Cache Cull Limits

bstop (cache cull limits settings)
- FS-Cache, Setting Cache Cull Limits

btrfs
- overview, Btrfs (Technology Preview)

Btrfs
- Btrfs Features, Btrfs Features
- Tech Preview, Btrfs

Btrfs Features
- Btrfs, Btrfs Features

C

cache back-end
- FS-Cache, FS-Cache

cache cull limits
- FS-Cache, Setting Cache Cull Limits

cache limitations with NFS
- FS-Cache, Cache Limitations With NFS

cache set up
- FS-Cache, Setting Up a Cache

cache sharing
- FS-Cache, Cache Sharing

cachefiles
- FS-Cache, FS-Cache

cachefilesd
- FS-Cache, Setting Up a Cache

caching, file system
- overview, File System Caching (Technology Preview)

CCW, channel command word
- storage considerations during installation, DASD and zFCP Devices on IBM System Z

changing dev_loss_tmo
- fibre channel
  - modifying link loss behavior, Fibre Channel

Changing the read/write state
- Online logical units, Changing the Read/Write State of an Online Logical Unit

channel command word (CCW)
- storage considerations during installation, DASD and zFCP Devices on IBM System Z

coherency data
- FS-Cache, FS-Cache

command timer (SCSI)
- Linux SCSI layer, Command Timer

commands
- volume_key, Commands

configuration
- discovery
  - iSCSI, iSCSI Discovery Configuration

configuring a tftp service for diskless clients
- diskless systems, Configuring a tftp Service for Diskless Clients

configuring an Ethernet interface to use FCoE
- FCoE, Configuring a Fibre-Channel Over Ethernet Interface

configuring DHCP for diskless clients
- diskless systems, Configuring DHCP for Diskless Clients

configuring RAID sets
- RAID, Configuring RAID Sets

controlling SCSI command timer and device status
- Linux SCSI layer, Controlling the SCSI Command Timer and Device Status

creating
- ext4, Creating an Ext4 File System
- XFS, Creating an XFS File System

cumulative mode (xfsrestore)
- XFS, Cumulative Mode for xfsrestore

D

DASD and zFCP devices on IBM System z
- storage considerations during installation, DASD and zFCP Devices on IBM System Z

debugfs (other ext4 file system utilities)
- ext4, Other Ext4 File System Utilities

deployment
- solid state disks, Deployment Considerations

deployment guidelines

- solid state disks, Solid-State Disk Deployment Guidelines

determining remote port states
- fibre channel
  - modifying link loss behavior, Fibre Channel

dev directory, The /dev/ Directory

device status
- Linux SCSI layer, Device States

device-mapper multipathing, DM-Multipath

devices, removing, Removing a Storage Device

dev_loss_tmo
- fibre channel
  - modifying link loss behavior, Fibre Channel
- fibre channel API, Fibre Channel API

dev_loss_tmo, changing
- fibre channel
  - modifying link loss behavior, Fibre Channel

df , Gathering File System Information

DHCP, configuring
- diskless systems, Configuring DHCP for Diskless Clients

DIF/DIX-enabled block devices
- storage considerations during installation, Block Devices with DIF/DIX Enabled

direct map support (autofs version 5)
- NFS, Improvements in autofs Version 5 over Version 4

directories
- /boot/ , The /boot/ Directory
- /dev/ , The /dev/ Directory
- /etc/ , The /etc/ Directory
- /lib/ , The /lib/ Directory
- /media/ , The /media/ Directory
- /mnt/ , The /mnt/ Directory
- /opt/ , The /opt/ Directory
- /proc/ , The /proc/ Directory
- /sbin/ , The /sbin/ Directory
- /srv/ , The /srv/ Directory
- /sys/ , The /sys/ Directory
- /usr/ , The /usr/ Directory
- /var/ , The /var/ Directory

dirty logs (repairing XFS file systems)
- XFS, Repairing an XFS File System

disabling NOP-Outs
- iSCSI configuration, iSCSI Root

disabling write caches
- write barriers, Disabling Write Caches

discovery
- iSCSI, iSCSI Discovery Configuration

disk quotas, Disk Quotas
- additional resources, Disk Quota References
- assigning per file system, Setting the Grace Period for Soft Limits
- assigning per group, Assigning Quotas per Group
- assigning per user, Assigning Quotas per User
- disabling, Enabling and Disabling
- enabling, Configuring Disk Quotas, Enabling and Disabling
  - /etc/fstab, modifying, Enabling Quotas
  - creating quota files, Creating the Quota Database Files
  - quotacheck, running, Creating the Quota Database Files
- grace period, Assigning Quotas per User
- hard limit, Assigning Quotas per User
- management of, Managing Disk Quotas
  - quotacheck command, using to check, Keeping Quotas Accurate
  - reporting, Reporting on Disk Quotas
- soft limit, Assigning Quotas per User

disk storage (see disk quotas)
- parted (see parted)

diskless systems
- DHCP, configuring, Configuring DHCP for Diskless Clients
- exported file systems, Configuring an Exported File System for Diskless Clients
- network booting service, Setting Up A Remote Diskless System
- remote diskless systems, Setting Up A Remote Diskless System
- required packages, Setting Up A Remote Diskless System
- tftp service, configuring, Configuring a tftp Service for Diskless Clients

dm-multipath
- iSCSI configuration, iSCSI Settings With dm-multipath

dmraid
- RAID, dmraid

dmraid (configuring RAID sets)
- RAID, dmraid

documentation
- LVM, LVM References

drivers (native), fibre channel, Native Fibre Channel Drivers and Capabilities

du , Gathering File System Information

dump levels
- XFS, Backup and Restoration of XFS File Systems

E

e2fsck, Reverting to an Ext2 File System

e2image (other ext4 file system utilities)
- ext4, Other Ext4 File System Utilities

e2label
- ext4, Other Ext4 File System Utilities

e2label (other ext4 file system utilities)
- ext4, Other Ext4 File System Utilities

ecryptfs
- overview, File System Encryption (Technology Preview)

eCryptfs
- file system types, Encrypted File System
- mount settings for encrypted file systems, Mounting a File System as Encrypted
- mounting, Mounting a File System as Encrypted
- mounting a file system as encrypted, Mounting a File System as Encrypted

editing a logical volume
- LVM, Editing a Logical Volume

enablind/disabling
- write barriers, Enabling/Disabling Write Barriers

encrypted file system
- mount settings for encrypted file systems, Mounting a File System as Encrypted
- mounting, Mounting a File System as Encrypted
- mounting a file system as encrypted, Mounting a File System as Encrypted

encryption, file system
- overview, File System Encryption (Technology Preview)

enhanced LDAP support (autofs version 5)
- NFS, Improvements in autofs Version 5 over Version 4

error messages
- write barriers, Enabling/Disabling Write Barriers

etc directory, The /etc/ Directory

expert mode (xfs_quota)
- XFS, XFS Quota Management

exported file systems
- diskless systems, Configuring an Exported File System for Diskless Clients

ext2
- reverting from ext3, Reverting to an Ext2 File System

ext3
- converting from ext2, Converting to an Ext3 File System
- creating, Creating an Ext3 File System
- features, The Ext3 File System

ext4
- allocation features, The Ext4 File System
- creating, Creating an Ext4 File System
- debugfs (other ext4 file system utilities), Other Ext4 File System Utilities
- e2image (other ext4 file system utilities), Other Ext4 File System Utilities
- e2label, Other Ext4 File System Utilities
- e2label (other ext4 file system utilities), Other Ext4 File System Utilities
- file system types, The Ext4 File System
- fsync(), The Ext4 File System
- main features, The Ext4 File System
- mkfs.ext4, Creating an Ext4 File System
- mounting, Mounting an Ext4 File System
- nobarrier mount option, Mounting an Ext4 File System
- other file system utilities, Other Ext4 File System Utilities
- quota (other ext4 file system utilities), Other Ext4 File System Utilities
- resize2fs (resizing ext4), Resizing an Ext4 File System
- resizing, Resizing an Ext4 File System
- stride (specifying stripe geometry), Creating an Ext4 File System
- stripe geometry, Creating an Ext4 File System
- stripe-width (specifying stripe geometry), Creating an Ext4 File System
- tune2fs (mounting), Mounting an Ext4 File System
- write barriers, Mounting an Ext4 File System

extending a volume group
- LVM, Extending a Volume Group

extents, migration of
- LVM, Migrating Extents

F

fast_io_fail_tmo
- fibre channel API, Fibre Channel API

FCoE
- configuring an Ethernet interface to use FCoE, Configuring a Fibre-Channel Over Ethernet Interface
- fibre channel over ethernet, Configuring a Fibre-Channel Over Ethernet Interface
- required packages, Configuring a Fibre-Channel Over Ethernet Interface
- storage considerations during installation, Updates to Storage Configuration During Installation

feedback
- contact information for this manual, We Need Feedback

FHS, Overview of Filesystem Hierarchy Standard (FHS), FHS Organization
- (see also file system)

fibre channel
- online storage, Fibre Channel

fibre channel API, Fibre Channel API

fibre channel drivers (native), Native Fibre Channel Drivers and Capabilities

fibre channel over ethernet
- FCoE, Configuring a Fibre-Channel Over Ethernet Interface

fibre-channel over ethernet
- storage considerations during installation, Updates to Storage Configuration During Installation

file system
- FHS standard, FHS Organization
- hierarchy, Overview of Filesystem Hierarchy Standard (FHS)
- organization, FHS Organization
- structure, File System Structure and Maintenance

file system caching
- overview, File System Caching (Technology Preview)

file system encryption
- overview, File System Encryption (Technology Preview)

file system types
- encrypted file system, Encrypted File System
- ext4, The Ext4 File System
- GFS2, Global File System 2
- XFS, The XFS File System

file systems, Gathering File System Information
- ext2 (see ext2)
- ext3 (see ext3)

file systems, overview of supported types
- storage considerations during installation, Overview of Supported File Systems

findmnt (command)
- listing mounts, Listing Currently Mounted File Systems

fs-cache
- overview, File System Caching (Technology Preview)

FS-Cache
- bcull (cache cull limits settings), Setting Cache Cull Limits
- brun (cache cull limits settings), Setting Cache Cull Limits
- bstop (cache cull limits settings), Setting Cache Cull Limits
- cache back-end, FS-Cache
- cache cull limits, Setting Cache Cull Limits
- cache sharing, Cache Sharing
- cachefiles, FS-Cache
- cachefilesd, Setting Up a Cache
- coherency data, FS-Cache
- indexing keys, FS-Cache
- NFS (cache limitations with), Cache Limitations With NFS
- NFS (using with), Using the Cache With NFS
- performance guarantee, Performance Guarantee
- setting up a cache, Setting Up a Cache
- statistical information (tracking), Statistical Information
- tune2fs (setting up a cache), Setting Up a Cache

fsync()

- ext4, The Ext4 File System
- XFS, The XFS File System

G

getfacl , Retrieving ACLs

GFS2
- file system types, Global File System 2
- gfs2.ko, Global File System 2
- maximum size, Global File System 2

GFS2 file system maximum size, Global File System 2

gfs2.ko
- GFS2, Global File System 2

Global File System 2
- file system types, Global File System 2
- gfs2.ko, Global File System 2
- maximum size, Global File System 2

gquota/gqnoenforce
- XFS, XFS Quota Management

H

Hardware RAID (see RAID)

hardware RAID controller drivers
- RAID, Linux Hardware RAID controller drivers

help
- getting help, Do You Need Help?

hierarchy, file system, Overview of Filesystem Hierarchy Standard (FHS)

high-end arrays
- write barriers, High-End Arrays

host
- fibre channel API, Fibre Channel API

how write barriers work
- write barriers, How Write Barriers Work

I

I/O alignment and size, Storage I/O Alignment and Size
- ATA standards, ATA
- block device ioctls (userspace access), Block Device ioctls
- Linux I/O stack, Storage I/O Alignment and Size
- logical_block_size, Userspace Access
- LVM, Logical Volume Manager
- READ CAPACITY(16), SCSI
- SCSI standards, SCSI
- stacking I/O parameters, Stacking I/O Parameters
- storage access parameters, Parameters for Storage Access
- sysfs interface (userspace access), sysfs Interface

- tools (for partitioning and other file system functions), Partition and File System Tools
- userspace access, Userspace Access

I/O limit processing
- overview, I/O Limit Processing

I/O parameters stacking
- I/O alignment and size, Stacking I/O Parameters

I/O scheduler (tuning)
- solid state disks, I/O Scheduler

iface (configuring for iSCSI offload)
- offload and interface binding
  - iSCSI, Configuring an iface for iSCSI Offload

iface binding/unbinding
- offload and interface binding
  - iSCSI, Binding/Unbinding an iface to a Portal

iface configurations, viewing
- offload and interface binding
  - iSCSI, Viewing Available iface Configurations

iface for software iSCSI
- offload and interface binding
  - iSCSI, Configuring an iface for Software iSCSI

iface settings
- offload and interface binding
  - iSCSI, Viewing Available iface Configurations

importance of write barriers
- write barriers, Importance of Write Barriers

increasing file system size
- XFS, Increasing the Size of an XFS File System

indexing keys
- FS-Cache, FS-Cache

individual user
- volume_key, Using volume_key as an individual user

initiator implementations
- offload and interface binding
  - iSCSI, Viewing Available iface Configurations

inode64 mount option
- XFS, Mounting an XFS File System

installation storage configurations
- advanced path, Updates to Storage Configuration During Installation

- auto-partitioning and /home, Updates to Storage Configuration During Installation
- basic path, Updates to Storage Configuration During Installation
- channel command word (CCW), DASD and zFCP Devices on IBM System Z
- DASD and zFCP devices on IBM System z, DASD and zFCP Devices on IBM System Z
- DIF/DIX-enabled block devices, Block Devices with DIF/DIX Enabled
- fibre-channel over ethernet, Updates to Storage Configuration During Installation
- file systems, overview of supported types, Overview of Supported File Systems
- iSCSI detection and configuration, iSCSI Detection and Configuration
- LUKS/dm-crypt, encrypting block devices using, Encrypting Block Devices Using LUKS
- separate partitions (for /home, /opt, /usr/local), Separate Partitions for /home, /opt, /usr/local
- stale BIOS RAID metadata, Stale BIOS RAID Metadata
- storage device filter interface, Updates to Storage Configuration During Installation
- updates, Storage Considerations During Installation
- what's new, Storage Considerations During Installation

installer support
- RAID, RAID Support in the Installer

interactive operation (xfsrestore)
- XFS, Interactive Operation

interconnects (scanning)
- iSCSI, Scanning iSCSI Interconnects

introduction, Overview

iSCSI
- discovery, iSCSI Discovery Configuration
  - configuration, iSCSI Discovery Configuration
  - record types, iSCSI Discovery Configuration
- offload and interface binding, Configuring iSCSI Offload and Interface Binding
  - binding/unbinding an iface to a portal, Binding/Unbinding an iface to a Portal
  - iface (configuring for iSCSI offload), Configuring an iface for iSCSI Offload
  - iface configurations, viewing, Viewing Available iface Configurations
  - iface for software iSCSI, Configuring an iface for Software iSCSI
  - iface settings, Viewing Available iface Configurations
  - initiator implementations, Viewing Available iface Configurations
  - software iSCSI, Configuring an iface for Software iSCSI
  - viewing available iface configurations, Viewing Available iface Configurations
- scanning interconnects, Scanning iSCSI Interconnects
- software iSCSI, Configuring an iface for Software iSCSI
- target set up, iSCSI Target Set up
- targets, Logging in to an iSCSI Target
  - logging in, Logging in to an iSCSI Target

iSCSI API, iSCSI API

iSCSI detection and configuration
- storage considerations during installation, iSCSI Detection and Configuration

iSCSI logical unit, resizing, Resizing an iSCSI Logical Unit

iSCSI root
- iSCSI configuration, iSCSI Root

issue_lip
- fibre channel API, Fibre Channel API

K

known issues
- adding/removing
  - LUN (logical unit number), Known Issues With rescan-scsi-bus.sh

L

lazy mount/unmount support (autofs version 5)
- NFS, Improvements in autofs Version 5 over Version 4

levels
- RAID, RAID Levels and Linear Support

lib directory, The /lib/ Directory

limit (xfs_quota expert mode)
- XFS, XFS Quota Management

linear RAID
- RAID, RAID Levels and Linear Support

Linux I/O stack
- I/O alignment and size, Storage I/O Alignment and Size

logging in
- iSCSI targets, Logging in to an iSCSI Target

logical volume, LVM (Logical Volume Manager)

logical volume, editing a
- LVM, Editing a Logical Volume

logical volumes, LVM (Logical Volume Manager)

logical_block_size
- I/O alignment and size, Userspace Access

LUKS/dm-crypt, encrypting block devices using
- storage considerations during installation, Encrypting Block Devices Using LUKS

LUN (logical unit number)
- adding/removing, Adding/Removing a Logical Unit Through rescan-scsi-bus.sh
  - known issues, Known Issues With rescan-scsi-bus.sh
  - required packages, Adding/Removing a Logical Unit Through rescan-scsi-bus.sh
  - rescan-scsi-bus.sh, Adding/Removing a Logical Unit Through rescan-scsi-bus.sh

LVM, LVM (Logical Volume Manager)

- adding a new volume group, Adding a New Volume Group
- additional resources, LVM References
- documentation, LVM References
- editing a logical volume, Editing a Logical Volume
- explanation of, LVM (Logical Volume Manager)
- extending a volume group, Extending a Volume Group
- extents, migration of, Migrating Extents
- I/O alignment and size, Logical Volume Manager
- logical volume, LVM (Logical Volume Manager)
- logical volume, editing a, Editing a Logical Volume
- logical volumes, LVM (Logical Volume Manager)
- migrating extents, Migrating Extents
- new hard disk, adding a, Adding a New Hard Disk Using LVM
- physical volume, LVM (Logical Volume Manager)
- system-config-lvm, Using system-config-lvm
- unallocated volumes, Utilizing Uninitialized Entities
- uninitialized entries, Utilizing Uninitialized Entities

LVM2
- explanation of, What is LVM2?

M

main features
- ext4, The Ext4 File System
- XFS, The XFS File System

maximum size
- GFS2, Global File System 2

maximum size, GFS2 file system, Global File System 2

mdadm (configuring RAID sets)
- RAID, mdadm

mdraid
- RAID, mdraid

media directory, The /media/ Directory

migrating extents
- LVM, Migrating Extents

mirroring
- RAID, RAID Levels and Linear Support

mkfs , Formatting and Labeling the Partition

mkfs.ext4
- ext4, Creating an Ext4 File System

mkfs.xfs
- XFS, Creating an XFS File System

mkpart , Making the Partition

mnt directory, The /mnt/ Directory

modifying link loss behavior, Modifying Link Loss Behavior

- fibre channel, Fibre Channel

mount (client configuration)
- NFS, NFS Client Configuration

mount (command), Using the mount Command
- listing mounts, Listing Currently Mounted File Systems
- mounting a file system, Mounting a File System
- moving a mount point, Moving a Mount Point
- options, Specifying the Mount Options
- shared subtrees, Sharing Mounts
  - private mount, Sharing Mounts
  - shared mount, Sharing Mounts
  - slave mount, Sharing Mounts
  - unbindable mount, Sharing Mounts

mount settings for encrypted file systems
- encrypted file system, Mounting a File System as Encrypted

mounting, Mounting a File System
- encrypted file system, Mounting a File System as Encrypted
- ext4, Mounting an Ext4 File System
- XFS, Mounting an XFS File System

mounting a file system as encrypted
- encrypted file system, Mounting a File System as Encrypted

moving a mount point, Moving a Mount Point

multiple master map entries per autofs mount point (autofs version 5)
- NFS, Improvements in autofs Version 5 over Version 4

N

native fibre channel drivers, Native Fibre Channel Drivers and Capabilities

network booting service
- diskless systems, Setting Up A Remote Diskless System

Network File System (see NFS)

new hard disk, adding a
- LVM, Adding a New Hard Disk Using LVM

NFS
- /etc/fstab , Mounting NFS File Systems using /etc/fstab
- /local/directory (client configuration, mounting), NFS Client Configuration
- /remote/export (client configuration, mounting), NFS Client Configuration
- additional resources, References
  - installed documentation, Installed Documentation
  - related books, Related Books
  - useful websites, Useful Websites
- autofs
  - augmenting, Overriding or Augmenting Site Configuration Files
  - configuration, autofs Configuration
  - LDAP, Using LDAP to Store Automounter Maps

- autofs version 5, Improvements in autofs Version 5 over Version 4
- client
  - autofs , autofs
  - configuration, NFS Client Configuration
  - mount options, Common NFS Mount Options
- condrestart, Starting and Stopping NFS
- configuration with firewall, Running NFS Behind a Firewall
- direct map support (autofs version 5), Improvements in autofs Version 5 over Version 4
- enhanced LDAP support (autofs version 5), Improvements in autofs Version 5 over Version 4
- FS-Cache, Using the Cache With NFS
- hostname formats, Hostname Formats
- how it works, How NFS Works
- introducing, Network File System (NFS)
- lazy mount/unmount support (autofs version 5), Improvements in autofs Version 5 over Version 4
- mount (client configuration), NFS Client Configuration
- multiple master map entries per autofs mount point (autofs version 5), Improvements in autofs Version 5 over Version 4
- options (client configuration, mounting), NFS Client Configuration
- overriding/augmenting site configuration files (autofs), autofs Configuration
- proper nsswitch configuration (autofs version 5), use of, Improvements in autofs Version 5 over Version 4
- RDMA, NFS over RDMA
- reloading, Starting and Stopping NFS
- required services, Required Services
- restarting, Starting and Stopping NFS
- rfc2307bis (autofs), Using LDAP to Store Automounter Maps
- rpcbind , NFS and rpcbind
- security, Securing NFS
  - file permissions, File Permissions
  - NFSv2/NFSv3 host access, NFS Security with AUTH_SYS and export controls
  - NFSv4 host access, NFS security with AUTH_GSS
- server (client configuration, mounting), NFS Client Configuration
- server configuration, NFS Server Configuration
  - /etc/exports , The /etc/exports Configuration File
  - exportfs command, The exportfs Command
  - exportfs command with NFSv4, Using exportfs with NFSv4
- starting, Starting and Stopping NFS
- status, Starting and Stopping NFS
- stopping, Starting and Stopping NFS
- storing automounter maps, using LDAP to store (autofs), Overriding or Augmenting Site Configuration Files
- TCP, How NFS Works
- troubleshooting NFS and rpcbind, Troubleshooting NFS and rpcbind
- UDP, How NFS Works
- write barriers, NFS

NFS (cache limitations with)

- FS-Cache, Cache Limitations With NFS

NFS (using with)

- FS-Cache, Using the Cache With NFS

nobarrier mount option
- ext4, Mounting an Ext4 File System
- XFS, Write Barriers

NOP-Out requests
- modifying link loss
  - iSCSI configuration, NOP-Out Interval/Timeout

NOP-Outs (disabling)
- iSCSI configuration, iSCSI Root

O

offline status
- Linux SCSI layer, Controlling the SCSI Command Timer and Device Status

offload and interface binding
- iSCSI, Configuring iSCSI Offload and Interface Binding

Online logical units
- Changing the read/write state, Changing the Read/Write State of an Online Logical Unit

online storage
- fibre channel, Fibre Channel
- overview, Online Storage Management
  - sysfs, Online Storage Management
- troubleshooting, Online Storage Configuration Troubleshooting

opt directory, The /opt/ Directory

options (client configuration, mounting)
- NFS, NFS Client Configuration

other file system utilities
- ext4, Other Ext4 File System Utilities

overriding/augmenting site configuration files (autofs)
- NFS, autofs Configuration

overview, Overview
- btrfs, Btrfs (Technology Preview)
- caching, file system, File System Caching (Technology Preview)
- ecryptfs, File System Encryption (Technology Preview)
- encryption, file system, File System Encryption (Technology Preview)
- file system caching, File System Caching (Technology Preview)
- file system encryption, File System Encryption (Technology Preview)
- fs-cache, File System Caching (Technology Preview)
- I/O limit processing, I/O Limit Processing
- online storage, Online Storage Management
- technology preview, File System Encryption (Technology Preview)

P

Parallel NFS
- pNFS, pNFS

parameters for storage access
- I/O alignment and size, Parameters for Storage Access

parity
- RAID, RAID Levels and Linear Support

parted , Partitions
- creating partitions, Creating a Partition
- overview, Partitions
- removing partitions, Removing a Partition
- resizing partitions, Resizing a Partition
- selecting device, Viewing the Partition Table
- table of commands, Partitions
- viewing partition table, Viewing the Partition Table

partition table
- viewing, Viewing the Partition Table

partitions
- creating, Creating a Partition
- formatting
  - mkfs , Formatting and Labeling the Partition
- making
  - mkpart , Making the Partition
- removing, Removing a Partition
- resizing, Resizing a Partition
- viewing list, Viewing the Partition Table

path to storage devices, adding, Adding a Storage Device or Path

path to storage devices, removing, Removing a Path to a Storage Device

performance guarantee
- FS-Cache, Performance Guarantee

persistent naming, Persistent Naming

physical volume, LVM (Logical Volume Manager)

pNFS
- Parallel NFS, pNFS

port states (remote), determining
- fibre channel
  - modifying link loss behavior, Fibre Channel

pquota/pqnoenforce
- XFS, XFS Quota Management

private mount, Sharing Mounts

proc directory, The /proc/ Directory

processing, I/O limit

- overview, I/O Limit Processing

project limits (setting)
- XFS, Setting Project Limits

proper nsswitch configuration (autofs version 5), use of
- NFS, Improvements in autofs Version 5 over Version 4

Q

queue_if_no_path
- iSCSI configuration, iSCSI Settings With dm-multipath
- modifying link loss
  - iSCSI configuration, replacement_timeout

quota (other ext4 file system utilities)
- ext4, Other Ext4 File System Utilities

quota management
- XFS, XFS Quota Management

quotacheck , Creating the Quota Database Files

quotacheck command
- checking quota accuracy with, Keeping Quotas Accurate

quotaoff , Enabling and Disabling

quotaon , Enabling and Disabling

R

RAID
- advanced RAID device creation, Advanced RAID Device Creation
- Anaconda support, RAID Support in the Installer
- configuring RAID sets, Configuring RAID Sets
- dmraid, dmraid
- dmraid (configuring RAID sets), dmraid
- explanation of, Redundant Array of Independent Disks (RAID)
- Hardware RAID, RAID Types
- hardware RAID controller drivers, Linux Hardware RAID controller drivers
- installer support, RAID Support in the Installer
- level 0, RAID Levels and Linear Support
- level 1, RAID Levels and Linear Support
- level 4, RAID Levels and Linear Support
- level 5, RAID Levels and Linear Support
- levels, RAID Levels and Linear Support
- linear RAID, RAID Levels and Linear Support
- mdadm (configuring RAID sets), mdadm
- mdraid, mdraid
- mirroring, RAID Levels and Linear Support
- parity, RAID Levels and Linear Support
- reasons to use, Redundant Array of Independent Disks (RAID)
- Software RAID, RAID Types
- striping, RAID Levels and Linear Support
- subsystems of RAID, Linux RAID Subsystems

RDMA

- NFS, NFS over RDMA

READ CAPACITY(16)
- I/O alignment and size, SCSI

record types
- discovery
  - iSCSI, iSCSI Discovery Configuration

Red Hat Enterprise Linux-specific file locations
- /etc/sysconfig/ , Special Red Hat Enterprise Linux File Locations
  - (see also sysconfig directory)

- /var/cache/yum , Special Red Hat Enterprise Linux File Locations
- /var/lib/rpm/ , Special Red Hat Enterprise Linux File Locations

remote diskless systems
- diskless systems, Setting Up A Remote Diskless System

remote port
- fibre channel API, Fibre Channel API

remote port states, determining
- fibre channel
  - modifying link loss behavior, Fibre Channel

removing devices, Removing a Storage Device

removing paths to a storage device, Removing a Path to a Storage Device

repairing file system
- XFS, Repairing an XFS File System

repairing XFS file systems with dirty logs
- XFS, Repairing an XFS File System

replacement_timeout
- modifying link loss
  - iSCSI configuration, SCSI Error Handler, replacement_timeout

replacement_timeoutM
- iSCSI configuration, iSCSI Root

report (xfs_quota expert mode)
- XFS, XFS Quota Management

required packages
- adding/removing
  - LUN (logical unit number), Adding/Removing a Logical Unit Through rescan-scsi-bus.sh

- diskless systems, Setting Up A Remote Diskless System
- FCoE, Configuring a Fibre-Channel Over Ethernet Interface

rescan-scsi-bus.sh
- adding/removing

- LUN (logical unit number), Adding/Removing a Logical Unit Through rescan-scsi-bus.sh

resize2fs, Reverting to an Ext2 File System

resize2fs (resizing ext4)
- ext4, Resizing an Ext4 File System

resized logical units, resizing, Resizing an Online Logical Unit

resizing
- ext4, Resizing an Ext4 File System

resizing an iSCSI logical unit, Resizing an iSCSI Logical Unit

resizing multipath device
- resizing online resized logical units, Updating the Size of Your Multipath Device

resizing resized logical units, Resizing an Online Logical Unit

restoring a backup
- XFS, Backup and Restoration of XFS File Systems

rfc2307bis (autofs)
- NFS, Using LDAP to Store Automounter Maps

rpcbind , NFS and rpcbind
- (see also NFS)
- NFS, Troubleshooting NFS and rpcbind
- rpcinfo , Troubleshooting NFS and rpcbind
- status, Starting and Stopping NFS

rpcinfo , Troubleshooting NFS and rpcbind

running sessions, retrieving information about
- iSCSI API, iSCSI API

running status
- Linux SCSI layer, Controlling the SCSI Command Timer and Device Status

S

sbin directory, The /sbin/ Directory

scanning interconnects
- iSCSI, Scanning iSCSI Interconnects

scanning storage interconnects, Scanning Storage Interconnects

SCSI command timer
- Linux SCSI layer, Command Timer

SCSI Error Handler
- modifying link loss
  - iSCSI configuration, SCSI Error Handler

SCSI standards
- I/O alignment and size, SCSI

separate partitions (for /home, /opt, /usr/local)

- storage considerations during installation, Separate Partitions for /home, /opt, /usr/local

server (client configuration, mounting)
- NFS, NFS Client Configuration

setfacl , Setting Access ACLs

setting up a cache
- FS-Cache, Setting Up a Cache

shared mount, Sharing Mounts

shared subtrees, Sharing Mounts
- private mount, Sharing Mounts
- shared mount, Sharing Mounts
- slave mount, Sharing Mounts
- unbindable mount, Sharing Mounts

simple mode (xfsrestore)
- XFS, Simple Mode for xfsrestore

slave mount, Sharing Mounts

software iSCSI
- iSCSI, Configuring an iface for Software iSCSI
- offload and interface binding
  - iSCSI, Configuring an iface for Software iSCSI

Software RAID (see RAID)

solid state disks
- deployment, Deployment Considerations
- deployment guidelines, Solid-State Disk Deployment Guidelines
- I/O scheduler (tuning), I/O Scheduler
- SSD, Solid-State Disk Deployment Guidelines
- swap (tuning), Swap
- throughput classes, Solid-State Disk Deployment Guidelines
- TRIM command, Solid-State Disk Deployment Guidelines
- tuning, Tuning Considerations
- virtual memory (tuning), Virtual Memory

specific session timeouts, configuring
- iSCSI configuration, Configuring Timeouts for a Specific Session

srv directory, The /srv/ Directory

SSD
- solid state disks, Solid-State Disk Deployment Guidelines

stacking I/O parameters
- I/O alignment and size, Stacking I/O Parameters

stale BIOS RAID metadata
- storage considerations during installation, Stale BIOS RAID Metadata

star , Archiving File Systems With ACLs

statistical information (tracking)

- FS-Cache, Statistical Information

storage access parameters
- I/O alignment and size, Parameters for Storage Access

storage considerations during installation
- advanced path, Updates to Storage Configuration During Installation
- auto-partitioning and /home, Updates to Storage Configuration During Installation
- basic path, Updates to Storage Configuration During Installation
- channel command word (CCW), DASD and zFCP Devices on IBM System Z
- DASD and zFCP devices on IBM System z, DASD and zFCP Devices on IBM System Z
- DIF/DIX-enabled block devices, Block Devices with DIF/DIX Enabled
- fibre-channel over Ethernet (FCoE), Updates to Storage Configuration During Installation
- file systems, overview of supported types, Overview of Supported File Systems
- iSCSI detection and configuration, iSCSI Detection and Configuration
- LUKS/dm-crypt, encrypting block devices using, Encrypting Block Devices Using LUKS
- separate partitions (for /home, /opt, /usr/local), Separate Partitions for /home, /opt, /usr/local
- stale BIOS RAID metadata, Stale BIOS RAID Metadata
- storage device filter interface, Updates to Storage Configuration During Installation
- updates, Storage Considerations During Installation
- what's new, Storage Considerations During Installation

storage device filter interface
- storage considerations during installation, Updates to Storage Configuration During Installation

storage interconnects, scanning, Scanning Storage Interconnects

storing automounter maps, using LDAP to store (autofs)
- NFS, Overriding or Augmenting Site Configuration Files

stride (specifying stripe geometry)
- ext4, Creating an Ext4 File System

stripe geometry
- ext4, Creating an Ext4 File System

stripe-width (specifying stripe geometry)
- ext4, Creating an Ext4 File System

striping
- RAID, RAID Levels and Linear Support
- RAID fundamentals, Redundant Array of Independent Disks (RAID)

su (mkfs.xfs sub-options)
- XFS, Creating an XFS File System

subsystems of RAID
- RAID, Linux RAID Subsystems

suspending

- XFS, Suspending an XFS File System

sw (mkfs.xfs sub-options)
- XFS, Creating an XFS File System

swap (tuning)
- solid state disks, Swap

swap space, Swap Space
- creating, Adding Swap Space
- expanding, Adding Swap Space
- explanation of, Swap Space
- file
  - creating, Creating a Swap File, Removing a Swap File
- LVM2
  - creating, Creating an LVM2 Logical Volume for Swap
  - extending, Extending Swap on an LVM2 Logical Volume
  - reducing, Reducing Swap on an LVM2 Logical Volume
  - removing, Removing an LVM2 Logical Volume for Swap
- moving, Moving Swap Space
- recommended size, Swap Space
- removing, Removing Swap Space

symbolic links in /dev/disk
- persistent naming, Persistent Naming

sys directory, The /sys/ Directory

sysconfig directory, Special Red Hat Enterprise Linux File Locations

sysfs
- overview
  - online storage, Online Storage Management

sysfs interface (userspace access)
- I/O alignment and size, sysfs Interface

system information
- file systems, Gathering File System Information
  - /dev/shm , Gathering File System Information

T

taget set up
- iSCSI, iSCSI Target Set up

targets
- iSCSI, Logging in to an iSCSI Target

Tech Preview
- Btrfs, Btrfs

technology preview
- overview, File System Encryption (Technology Preview)

tftp service, configuring
- diskless systems, Configuring a tftp Service for Diskless Clients

throughput classes
- solid state disks, Solid-State Disk Deployment Guidelines

timeouts for a specific session, configuring
- iSCSI configuration, Configuring Timeouts for a Specific Session

tools (for partitioning and other file system functions)
- I/O alignment and size, Partition and File System Tools

tracking statistical information
- FS-Cache, Statistical Information

transport
- fibre channel API, Fibre Channel API

TRIM command
- solid state disks, Solid-State Disk Deployment Guidelines

troubleshooting
- online storage, Online Storage Configuration Troubleshooting

troubleshooting NFS and rpcbind
- NFS, Troubleshooting NFS and rpcbind

tune2fs
- converting to ext3 with, Converting to an Ext3 File System
- reverting to ext2 with, Reverting to an Ext2 File System

tune2fs (mounting)
- ext4, Mounting an Ext4 File System

tune2fs (setting up a cache)
- FS-Cache, Setting Up a Cache

tuning
- solid state disks, Tuning Considerations

U

udev
- persistent naming, WWID

udev rule (timeout)
- command timer (SCSI), Command Timer

umount, Unmounting a File System

unallocated volumes
- LVM, Utilizing Uninitialized Entities

unbindable mount, Sharing Mounts

uninitialized entries

- LVM, Utilizing Uninitialized Entities

Universally Unique Identifier (UUID)
- persistent naming, UUID and Other Persistent Identifiers

unmounting, Unmounting a File System

updates
- storage considerations during installation, Storage Considerations During Installation

uquota/uqnoenforce
- XFS, XFS Quota Management

userspace access
- I/O alignment and size, Userspace Access

userspace API files
- fibre channel API, Fibre Channel API

usr directory, The /usr/ Directory

UUID
- persistent naming, UUID and Other Persistent Identifiers

V

var directory, The /var/ Directory

var/lib/rpm/ directory, Special Red Hat Enterprise Linux File Locations

var/spool/up2date/ directory, Special Red Hat Enterprise Linux File Locations

verifying if a device is blocked
- fibre channel
  - modifying link loss behavior, Fibre Channel

version
- what is new
  - autofs, Improvements in autofs Version 5 over Version 4

viewing available iface configurations
- offload and interface binding
  - iSCSI, Viewing Available iface Configurations

virtual file system (/proc)
- /proc/devices, The /proc Virtual File System
- /proc/filesystems, The /proc Virtual File System
- /proc/mdstat, The /proc Virtual File System
- /proc/mounts, The /proc Virtual File System
- /proc/mounts/, The /proc Virtual File System
- /proc/partitions, The /proc Virtual File System

virtual memory (tuning)
- solid state disks, Virtual Memory

virtual storage, Virtual Storage

volume group, LVM (Logical Volume Manager)

volume_key
- commands, Commands
- individual user, Using volume_key as an individual user

W

what's new
- storage considerations during installation, Storage Considerations During Installation

World Wide Identifier (WWID)
- persistent naming, WWID

write barriers
- battery-backed write caches, Battery-Backed Write Caches
- definition, Write Barriers
- disabling write caches, Disabling Write Caches
- enablind/disabling, Enabling/Disabling Write Barriers
- error messages, Enabling/Disabling Write Barriers
- ext4, Mounting an Ext4 File System
- high-end arrays, High-End Arrays
- how write barriers work, How Write Barriers Work
- importance of write barriers, Importance of Write Barriers
- NFS, NFS
- XFS, Write Barriers

write caches, disabling
- write barriers, Disabling Write Caches

WWID
- persistent naming, WWID

X

XFS
- allocation features, The XFS File System
- backup/restoration, Backup and Restoration of XFS File Systems
- creating, Creating an XFS File System
- cumulative mode (xfsrestore), Cumulative Mode for xfsrestore
- dump levels, Backup and Restoration of XFS File Systems
- expert mode (xfs_quota), XFS Quota Management
- file system types, The XFS File System
- fsync(), The XFS File System
- gquota/gqnoenforce, XFS Quota Management
- increasing file system size, Increasing the Size of an XFS File System
- inode64 mount option, Mounting an XFS File System
- interactive operation (xfsrestore), Interactive Operation
- limit (xfs_quota expert mode), XFS Quota Management
- main features, The XFS File System
- mkfs.xfs, Creating an XFS File System
- mounting, Mounting an XFS File System
- nobarrier mount option, Write Barriers
- pquota/pqnoenforce, XFS Quota Management
- project limits (setting), Setting Project Limits
- quota management, XFS Quota Management
- repairing file system, Repairing an XFS File System
- repairing XFS file systems with dirty logs, Repairing an XFS File System

- report (xfs_quota expert mode), XFS Quota Management
- simple mode (xfsrestore), Simple Mode for xfsrestore
- su (mkfs.xfs sub-options), Creating an XFS File System
- suspending, Suspending an XFS File System
- sw (mkfs.xfs sub-options), Creating an XFS File System
- uquota/uqnoenforce, XFS Quota Management
- write barriers, Write Barriers
- xfsdump, Backup and Restoration of XFS File Systems
- xfsprogs, Suspending an XFS File System
- xfsrestore, Backup and Restoration of XFS File Systems
- xfs_admin, Other XFS File System Utilities
- xfs_bmap, Other XFS File System Utilities
- xfs_copy, Other XFS File System Utilities
- xfs_db, Other XFS File System Utilities
- xfs_freeze, Suspending an XFS File System
- xfs_fsr, Other XFS File System Utilities
- xfs_growfs, Increasing the Size of an XFS File System
- xfs_info, Other XFS File System Utilities
- xfs_mdrestore, Other XFS File System Utilities
- xfs_metadump, Other XFS File System Utilities
- xfs_quota, XFS Quota Management
- xfs_repair, Repairing an XFS File System

xfsdump
- XFS, Backup and Restoration of XFS File Systems

xfsprogs
- XFS, Suspending an XFS File System

xfsrestore
- XFS, Backup and Restoration of XFS File Systems

xfs_admin
- XFS, Other XFS File System Utilities

xfs_bmap
- XFS, Other XFS File System Utilities

xfs_copy
- XFS, Other XFS File System Utilities

xfs_db
- XFS, Other XFS File System Utilities

xfs_freeze
- XFS, Suspending an XFS File System

xfs_fsr
- XFS, Other XFS File System Utilities

xfs_growfs
- XFS, Increasing the Size of an XFS File System

xfs_info
- XFS, Other XFS File System Utilities

xfs_mdrestore
- XFS, Other XFS File System Utilities

xfs_metadump
- XFS, Other XFS File System Utilities

xfs_quota
- XFS, XFS Quota Management

xfs_repair
- XFS, Repairing an XFS File System